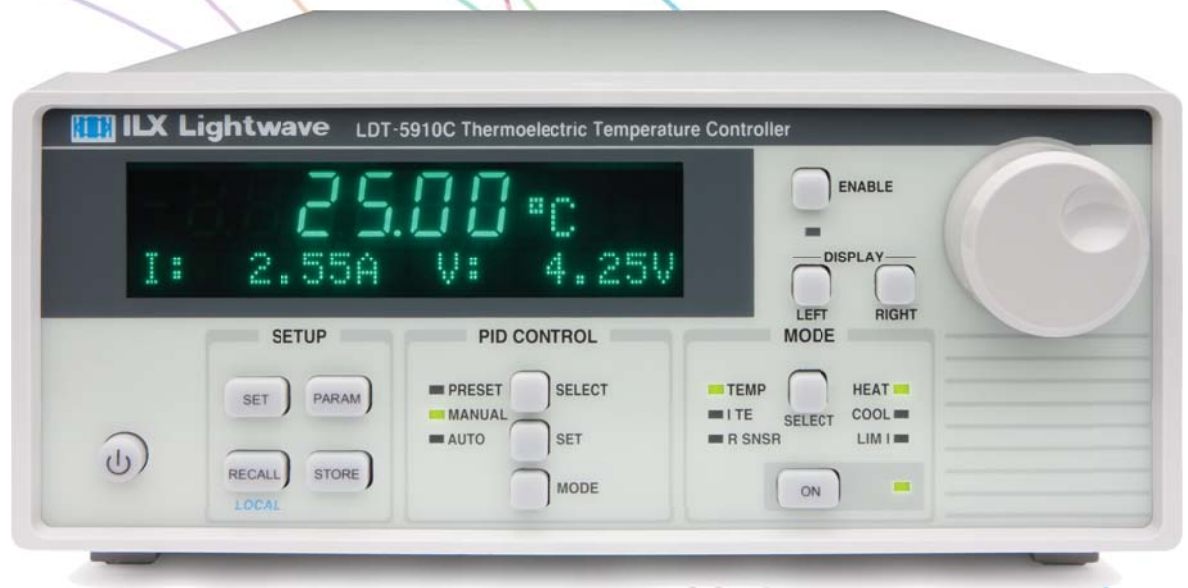


User's Guide

Thermoelectric Temperature Controllers
LDT-5910C
LDT-5940C



 **ILX Lightwave®**
A Newport Corporation Brand

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Safety and Warranty Information

- ✓ Details about cautionary symbols
- ✓ Safety markings used on the instrument
- ✓ Information about the warranty
- ✓ Customer service contact information

Safety Information and the Manual

Throughout this manual, you will see the words **Caution** and **Warning** indicating potentially dangerous or hazardous situations which, if not avoided, could result in death, serious or minor injury, or damage to the product. Specifically:



Caution indicates a potentially hazardous situation which can result in minor or moderate injury or damage to the product or equipment.



Warning indicates a potentially dangerous situation which can result in serious injury or death.



Visible and/or invisible laser radiation. Avoid direct exposure to the beam.

General Safety Considerations

If any of the following conditions exist, or are even suspected, do not use the instrument until safe operation can be verified by trained service personnel:

- Visible damage
- Severe transport stress
- Prolonged storage under adverse conditions
- Failure to perform intended measurements or functions

If necessary, return the instrument to ILX Lightwave, or authorized local ILX Lightwave distributor, for service or repair to ensure that safety features are maintained.

All instruments returned to ILX Lightwave are required to have a Return Authorization Number assigned by an official representative of ILX Lightwave Corporation. See **Returning an Instrument** for more information.

Safety Symbols

This section describes the safety symbols and classifications.

Technical specifications including electrical ratings and weight are included within the manual. See the Table of Contents to locate the specifications and other product information. The following classifications are standard across all ILX Lightwave products:

- Indoor use only
- Ordinary Protection: This product is NOT protected against the harmful ingress of moisture.
- IEC Class I Equipment (grounded type)
- Mains supply voltage fluctuations are not to exceed $\pm 10\%$ of the nominal supply voltage.
- Pollution Degree II
- Installation (overvoltage) Category II for transient over-voltages
- Maximum Relative Humidity: $< 85\%$ RH, non-condensing
- Operating temperature range of $10\text{ }^{\circ}\text{C}$ to $40\text{ }^{\circ}\text{C}$
- Storage and transportation temperature of $-40\text{ }^{\circ}\text{C}$ to $70\text{ }^{\circ}\text{C}$
- Maximum altitude: 3000 m (9843 ft.)
- This equipment is suitable for continuous operation.

Safety Marking Symbols

This section provides a description of the safety marking symbols that appear on the instrument. These symbols provide information about potentially dangerous situations which can result in death, injury, or damage to the instrument and other components.



Caution, refer to manual



Earth ground Terminal



Alternating current



Visible and/or invisible laser radiation



Caution, risk of electric shock



Protective Conductor Terminal



Caution, hot surface



Frame or chassis terminal

Warranty

ILX Lightwave Corporation warrants this instrument to be free from defects in material and workmanship for a period of one year from date of shipment. During the warranty period, ILX will repair or replace the unit, at our option, without charge.

Limitations

This warranty does not apply to fuses, lamps, defects caused by abuse, modifications, or to use of the product for which it was not intended.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for any particular purpose. ILX Lightwave Corporation shall not be liable for any incidental, special, or consequential damages.

If a problem occurs, please contact ILX Lightwave Corporation with the instrument's serial number, and thoroughly describe the nature of the problem.

Returning an Instrument

If an instrument is to be shipped to ILX Lightwave for repair or service, be sure to:

- Obtain a Return Authorization number (RA) from ILX Customer Service.
- Attach a tag to the instrument identifying the owner and indicating the required service or repair. Include the instrument serial number from the rear panel of the instrument.
- Attach the anti-static protective caps that were shipped with the instrument.
- Place the instrument in the original packing container with at least 3 inches (7.5 cm) of compressible packaging material. Shipping damage is not covered by this warranty.
- Secure the packing box with fiber reinforced strapping tape or metal bands.
- Send the instrument, transportation pre-paid, to ILX Lightwave. Clearly write the return authorization number on the outside of the box and on the shipping paperwork. ILX Lightwave recommends you insure the shipment.
- If the original shipping container is not available, place your instrument in a container with at least 3 inches (7.5 cm) of compressible packaging material on all sides.

Repairs are made and the instrument returned transportation pre-paid. Repairs are warranted for the remainder of the original warranty or for 90 days, whichever is greater.

Claims for Shipping Damage

When you receive the instrument, inspect it immediately for any damage or shortages on the packing list. If the instrument is damaged, file a claim with the carrier. The factory will supply you with a quotation for estimated costs of repair. You must negotiate and settle with the carrier for the amount of damage.

Comments, Suggestions, and Problems

To ensure that you get the most out of your ILX Lightwave product, we ask that you direct any product operation or service related questions or comments to ILX Lightwave Customer Support. You may contact us in whatever way is most convenient:

Phone (800) 459-9459 or (406) 586-1244

Fax (406) 586-9405

On the web at: ilx.custhelp.com

Or mail to:

ILX Lightwave Corporation

31950 East Frontage Road

Bozeman, Montana, U.S.A 59715-8642

www.ilxlightwave.com

When you contact us, please have the following information:

- ✓ Model Number
- ✓ Serial Number
- ✓ End-user Name
- ✓ Company
- ✓ Phone
- ✓ Fax
- ✓ Description of what is connected to the ILX Lightwave instrument
- ✓ Description of the problem

If ILX Lightwave determines that a return to the factory is necessary, you are issued a Return Authorization (RA) number. Please mark this number on the outside of the shipping box.

You or your shipping service are responsible for any shipping damage when returning the instrument to ILX Lightwave; ILX recommends you insure the shipment. If the original shipping container is not available, place your instrument in a container with at least 3 inches (7.5 cm) of compressible packaging material on all sides.

We look forward to serving you even better in the future!

Chapter 1:

Introduction and Specifications

This chapter is an introduction to the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers.

- ✓ Safety Considerations and unpacking information
- ✓ Product Overview
- ✓ Options and accessories
- ✓ Specifications

Safety Considerations



If any of the following symptoms exist, or are even suspected, remove the LDT-5910C or LDT-5940C from service. Do not use the LDT-5910C or LDT-5940C until trained service personnel can verify safe operation.

- Visible damage
- Severe transport stress
- Prolonged storage under adverse conditions
- Failure to perform intended measurements or functions

If necessary, return the LDT-5910C or LDT-5940C to ILX Lightwave for service and repair to ensure that safety features are maintained.

Initial Inspection

When you receive your LDT-5910C or LDT-5940C Thermoelectric Temperature Controller, verify that the following items were shipped with the instrument

- LDT-5900C Series Thermoelectric Temperature Controller Manual
- Power Cord
- Shipping Kit

Shipping Kit

The shipping kit for the LDT-5910C and LDT-5940C Thermoelectric Temperature Controller includes a USB A/B cable and a CD containing the ILX Lightwave USB Driver.

Product Overview

The LDT-5910C and LDT-5940C are high performance thermoelectric temperature controllers that offers a flexible, extended temperature control range from -100 °C to +200 °C with a choice of temperature sensors. The LDT-5910C features a linear, bipolar output providing 32 Watts of power to drive most thermal loads. This output stage offers the low current noise necessary to achieve the temperature stability required to meet demanding low noise and frequency-stabilized laser applications. The LDT-5940C features a switching output providing 60 Watts of temperature control power for applications requiring increased cooling or heating capacity. The instruments support thermistor, platinum RTD, and IC temperature sensors. In addition, a unique linearized thermistor mode allows for the use of a standard 10 k Ω thermistor over an extended temperature range from -15 °C to 65 °C. A digital PID control loop delivers fast settling time while maintaining high stability. For quick setup the LDT-5910C and LDT-5940C incorporate pre-programmed PID values for common applications. In addition, a fast auto-tune algorithm is available to automatically adjust the PID constants to support a wide range of thermal loads. The GPIB and USB interfaces ensure trouble-free remote programming and readout.

Features of the LDT-5910C and LDT-5940C include:

- Precision setpoint resolution of ± 0.01 °C with long term temperature stability of ± 0.002 °C (LDT-5910C) and ± 0.003 °C (LDT-5940C)
- Unique, linearized thermistor mode allows a standard 10 k Ω thermistor to be used over the range from -15 °C to 65 °C
- Pseudo 4-Wire Sensor and TEC Measurement (LDT-5940C only)
- Fully programmable PID control loop with twelve preset PID values
- Auto-tune algorithm automatically adjusts PID constants for a wide range of loads
- External analog temperature control input
- Independent heating and cooling current limits
- TE voltage measurement
- Heat only control mode
- Remote commands in LDT-5910C and LDT-5940C are compatible with LDT-5910B remote commands
- GPIB/IEEE 488 and USB Interfaces
- Normally open and normally closed output interlock
- Variable speed external fan control

If cleaning is required, use a clean dry cloth. Do not use solvents.

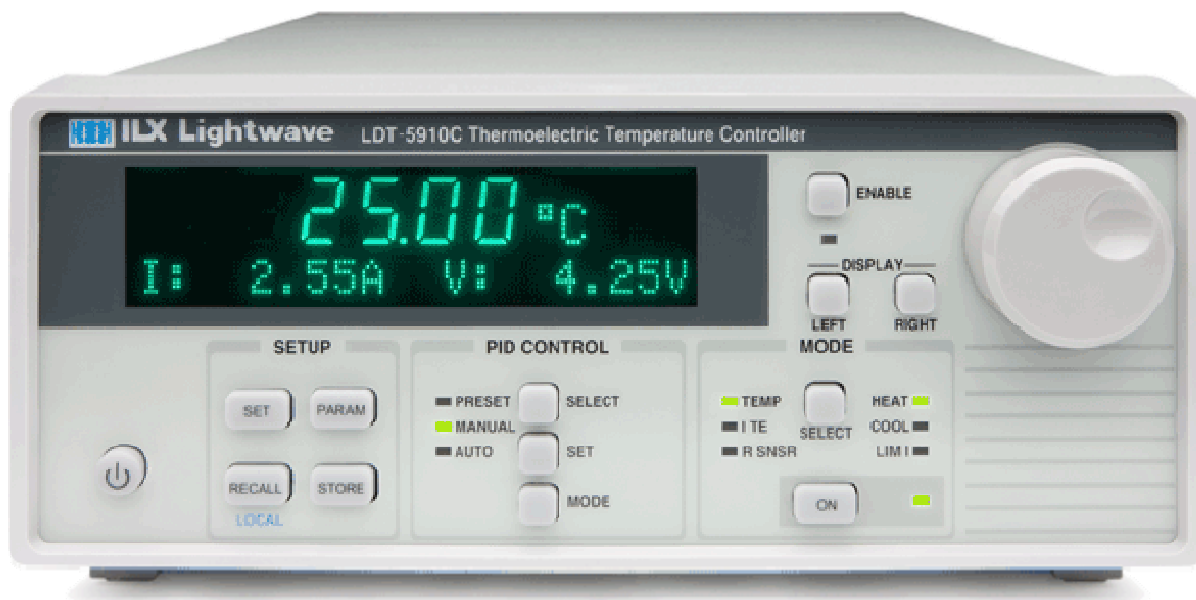


Figure 1.1 – LDT-5910C and LDT-5940C Front Panel



Figure 1.2 – LDT-5910C Rear Panel

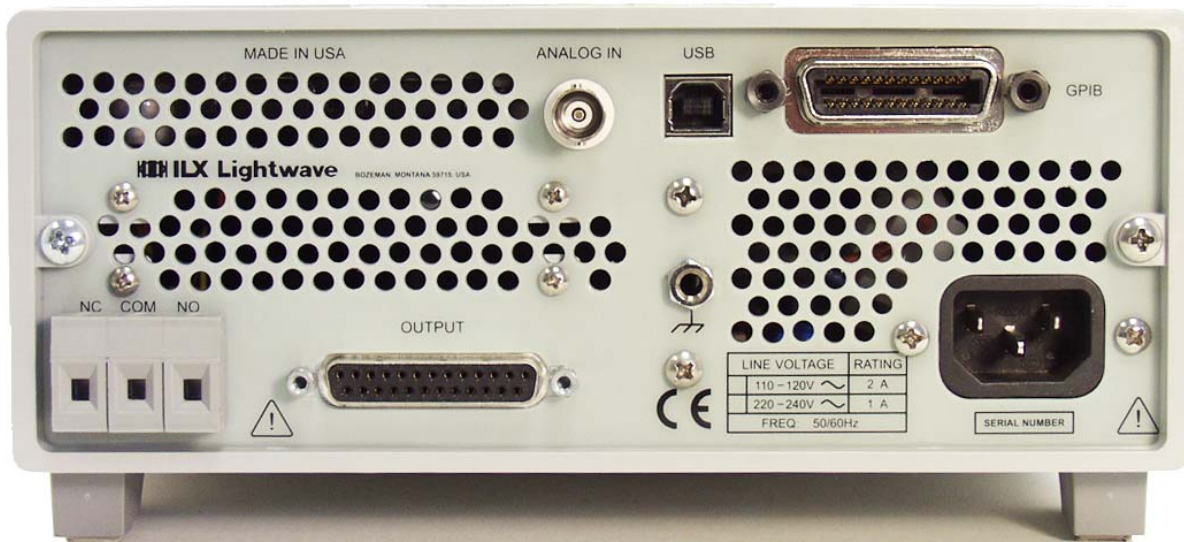


Figure 1.4 – LDT-5940C Rear Panel

Options and Accessories

Options and accessories available for LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers include the following:

DESCRIPTION	MODEL / PART NUMBER
Single Rack Mount Kit	RM-144
Dual Rack Mount Kit	RM-145
Temperature Controller Interconnect Cable (terminated with 9-pin DSUB)	CC-505S [5910C only]
Temperature Controller Interconnect Cable (unterminated)	CC-501S [5910C only]
10 Amp TE Interconnect Cable (unterminated without fan connections)	CC-591H [5940C only]
10 Amp TE Interconnect Cable (unterminated with fan connections)	CC-594H [5940C only]
5 Amp TE/LDM Interconnect Cable (terminated with 9-pin DSUB)	CC-595S [5940C only]
10 Amp TE Interconnect Cable (terminated with 7W2 DSUB)	CC-596H [5940C only]
Calibrated 10 k Ω Thermistor	TS-510
Uncalibrated 10 k Ω Thermistor	TS-520
Uncalibrated 5 k Ω Thermistor	TS-521
Uncalibrated 20 k Ω Thermistor	TS-523
Uncalibrated 100 k Ω Thermistor	TS-525
Uncalibrated AD590 IC Temperature Sensor	TS-530
Uncalibrated LM335 IC Temperature Sensor	TS-540
Unipolar Control Adapter	UCA-350
TO-Can Laser Diode Mount	LDM-4405
TO-Can Laser Diode Mount	LDM-4407
C-Mount Laser Diode Mount	LDM-4409
TO-Can Laser Diode Mount (with optional collimating lens)	LDM-4412
TELECOM Laser Diode Mount	LDM-4980
Production TO-Can Laser Diode Mount	LDM-4990

Specifications

CONTROL SYSTEM

Temperature Control Range ²

Thermistor Sensor:	-100 °C to +200 °C
IC Sensor:	-100 °C to +150 °C
RTD Sensor:	-100 °C to +200 °C

Temperature Setpoint and Measurement

Precision / Accuracy ³

0 °C:	±0.001 °C / ±0.01 °C
25 °C:	±0.002 °C / ±0.04 °C
50 °C:	±0.007 °C / ±0.15 °C
75 °C:	±0.05 °C / ±0.9 °C

Temperature Stability ⁴

1 hour:	±0.001 °C (LDT-5910C)
24 hours:	±0.002 °C (LDT-5910C)
1 hour:	±0.002 °C (LDT-5940C)
24 hours:	±0.003 °C (LDT-5940C)

SENSOR

Types

Thermistor (5910C):	NTC (2-wire)
Thermistor (5940C):	NTC (2 or 4-wire)
IC-V Semiconductor IC:	LM-335
	Voltage output, 5 to 14 mV/K
IC-I Semiconductor IC:	AD-590
	Current output, 1 µA/K
RTD Sensor (5910C):	Platinum 100 Ω/1000 Ω (2-wire)
RTD Sensor (5940C):	Platinum 100 Ω/1000 Ω (2 or 4-wire)

Thermistor Sensor Resistance

10 µA Bias Setting	
Range:	0 to 450 kΩ
Resolution (Display): ⁶	0.01 kΩ
Accuracy:	±180 Ω

100 µA Bias Setting	
Range:	0 to 45 kΩ
Resolution (Display): ⁶	0.001 kΩ
Accuracy:	±18 Ω

Linearized Thermistor Resistance

Range:	0 to 15 kΩ
Resolution (Display): ⁶	0.001 kΩ
Accuracy:	±10 Ω

IC-V Sensor Voltage

Nominal Bias:	1 mA
Range:	0 to 6 V
Resolution (Display): ⁶	0.0001 V
Accuracy:	±2 mV

IC-I Sensor Current

Nominal Bias:	5 to 15 V
Range:	0 to 600 µA
Resolution (Display): ⁶	0.001 µA
Accuracy:	±0.18 µA

RTD Sensor Resistance

1 mA Bias Setting	
Range:	0 to 1500 Ω
Resolution (Display): ⁶	0.01 Ω
Accuracy:	±0.8 Ω

2.5 mA Bias Setting	
Range:	0 to 200 Ω
Resolution (Display): ⁶	0.001 Ω
Accuracy:	±0.1 Ω

User Sensor Calibration

Thermistor:	Steinhart-Hart, 3 constants
IC Sensors:	Slope, Offset
RTD:	R ₀ , A, B, C

AUXILIARY I/O

Analog Control Input

Input Voltage Range:	-5 V to +5 V
Input Resistance:	>100 kΩ
Gain:	2 °C/V
Bandwidth	5 Hz
Interlock:	n/o and n/c relay contacts

External Fan Control Output

Output Voltage Range:	0 to +12 V
Maximum Current:	500 mA

TEC OUTPUT

Type (5910C):	Bidirectional, linear
(5940C):	Bidirectional, switch mode
Isolation:	Floating with respect to earth ground
Current Setpoint Range:	-4.00 A to +4.00 A (5910C) -5.00 A to +5.00 A (5940C)
Current Setpoint Resolution: ⁶	0.01 A
Current Setpoint Accuracy:	±0.05 A
Current Limit Range:	-4.05 A to +4.05 A (5910C) -5.05 A to +5.05 A (5940C)
Current Limit Accuracy:	±0.05 A
Voltage Measurement ⁷	
Range:	-8.00 V to +8.00 V (5910C) -12.00V to +12.00 V (5940C)
Resolution: ⁶	0.01 V
Accuracy:	±0.01 V
Compliance Voltage:	±8 V (5910C); ±12V (5940C)
Maximum Output Power:	32 W (5910C); 60 W (5940C)
Current Noise and Ripple: ⁵	<1 mA rms (5910C) <2 mA rms (5940C)

GENERAL

Connectors

TEC I/O:	Female 15-Pin D-sub (5910C) Female 25-Pin D-sub (5940C)
GPIO:	IEEE-488.1
USB:	2.0
Analog Input:	BNC

Power Requirements

LDT-5910C and 5940C:	110 - 130 VAC, 50/60 Hz, 1 A
LDT-5910C and 5940C:	220 - 240 VAC, 50/60 Hz, 0.5 A
LDT-5910CJ:	100 - 110 VAC, 50/60 Hz, 1 A

Size (HxWxD):

	102 mm x 216 mm x 356 mm (4.0" x 8.5 x 14.0")
Weight (LDT-5910C):	4.9 kg. (10.8 lbs.)
Weight (LDT-5940C):	3.8 kg. (8.3 lbs.)
Operating Temperature:	10 °C to 40 °C
Storage Temperature:	-40 °C to 70 °C
Humidity:	<85%, relative, non-condensing
Warm Up:	1 hour
Compliance:	CE

NOTES

1. All values are specified for an ambient temperature of 23 ± 5 °C after a 1 hour warm up unless otherwise specified.
2. Software limits of range. Actual range depends on the physical load, sensor type, and TEC module used.
3. Accuracy figures represent the uncertainty that the 5910C/40C adds to the measurement. This figure does not include the sensor calibration uncertainties. Thermistor accuracy figures are quoted for a typical 10k thermistor and 100 μ A current setting for -5 °C to 50 °C.
4. Temperature stability measurements made in a stable ambient environment ± 5 °C with a 10 k Ω thermistor on the 100 μ A setting after a 2 hour warm up period. Stability is defined as $\pm(T_{\text{max}} - T_{\text{min}})/2$ over the measurement period.
5. Measured over the full DC current range into a 1 Ω load.
6. Maximum resolution available when operating in the control mode (using the 7-segment display) resolution will be reduced when displayed on the lower display. In remote operation, 6 significant digits of resolution are reported.
7. Measured at the output connector. Users may enter in cable resistance to provide an accurate voltage measurement at the load.

In keeping with our commitment to continuous improvement, ILX Lightwave reserves the right to change specifications without notice and without liability for such changes.

Chapter 2:

General Operation

This chapter is an overview of the operation of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers.

- ✓ Power requirements
- ✓ Front panel operation
- ✓ General operating procedures

Grounding Requirements

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers come with a three conductor AC power cable. The power cable must be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adaptor with the grounding wire connected to an electrical ground (safety ground). ILX Lightwave recommends connecting the instrument only to properly earth grounded receptacles. The power cord connector and power cable meet IEC safety standards.

AC Line Power Requirements

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controller can be configured to operate at nominal line voltages of either 110 - 120 VAC or 220 - 240 VAC and for the LDT-5910CJ (100V) model 100 – 110 VAC. This is a factory fixed configuration which cannot be changed by the end user. Check to be sure that the voltage indicated on the back panel of the instrument matches the power line voltage in your area.

The Power Up Sequence



Prior to power up ensure the fan inlet located on the right hand side of the instrument has no obstructions that would impede airflow. In addition ensure there is no obstruction in the rear that may impede airflow.

With the LDT-5910C or LDT-5940C connected to an AC power source, pressing **POWER** supplies AC line power to the instrument and starts the following power up sequence where each display last two to three seconds.

- All front panel indicators are ON, all 7-segment displays indicate “8”
- All front panel indicators OFF
- Display shows the model number, the serial number and the firmware version of the controller

During the front panel indicator test, the LDT-5910C and LDT-5940C performs a self-test to ensure that the internal hardware and software are communicating. If the LDT-5910C and LDT-5940C cannot successfully complete the test, an error message is displayed. See Chapter 5 for a complete list of error messages. After the self test, the LDT-5910C and LDT-5940C configuration is set to the same state as when the power was last turned off.

To quickly set a different configuration you can use the recall function. See Store and Recall for more information.

Firmware Upgradeability

The firmware on the LDT-5910C and LDT-5940C can be reinstalled or upgraded via USB. Contact ILX Lightwave technical support for information on upgrading the software of the LDT-5910C and LDT-5940C.

GPIO Communication

The IEEE 488 GPIO interface connector is located on the rear panel, directly above the power input module (See Figure 1.2 on page 3 or Figure 1.4 on page 4). Attach the GPIO cable to the 24-pin connector located on the rear panel. The connector is tapered to ensure proper orientation. Finger tighten the two screws on the cable connector.

A total of 15 devices can be connected together on the same GPIO interface bus. The cables have single male/female connectors on each end so that several cables can be stacked. This allows more than one cable to be attached to any one device. However, the maximum length of the GPIO cables must not exceed 20 meters (65 feet) total, or 2 meters (6.5 feet) per device. As good practice the number of GPIO cables connected to one instrument should be limited to less than 6.

USB Communication

The USB connector is located on the back rear panel, next to the GPIO connector. This USB connector is the square "B"-style connector. A standard USB A/B cable is required to communicate with the instrument. To communicate with the instrument using USB, please install the Virtual Com Port Driver found on the accompanying CD or website prior to connecting the unit to the PC. Please refer to Chapter 3 for more detailed instructions on operating the instrument through USB.

Tilt Foot Adjustment

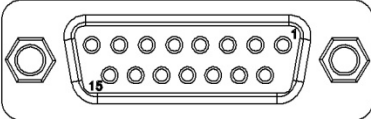
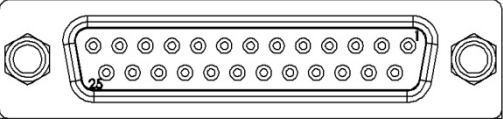
The LDT-5910C and LDT-5940C have front legs that extend to make it easier to view the display. To use them, rotate the legs downward until they lock into position.

Rack Mounting

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers may be rack mounted in a single or dual configuration by installing the appropriate rack mount flange on either side of the enclosure. All rack mount accessory kits contain detailed mounting instructions. Refer to the Options and Accessories table in Chapter 1 for applicable rack mount accessory part numbers.

Connections

Temperature Control Output: A 15-pin DSUB connector (5910C) or 25-pin DSUB connector (5940C) is located on the back panel of the instrument. The connections for each case are shown below.

LDT-5910C		LDT-5940C	
			
PIN NUMBER	CONNECTION	PIN NUMBER	CONNECTION
1	TE Module (+)	1	Sensor (+) Sense Terminal
2	TE Module (+)	2	Sensor (-) Sense Terminal
3	TE Module (-)	3	Fan (+)
4	TE Module (-)	4	N/C
5	TE Module Shield	5	N/C
6	Sensor Shield	6	Sensor / TE Module Shield
7	Sensor (+)	7	TE Module (+) Sense Terminal
8	Sensor (-)	8	TE Module (-) Sense Terminal
9	N/C	9	TE Module (+)
10	N/C	10	TE Module (+)
11	N/C	11	N/C
12	N/C	12	TE Module (-)
13	N/C	13	TE Module (-)
14	Fan (+)	14	Sensor (-)
15	Fan (-)	15	Sensor (+)
		16	Fan (-)
		17	Cable ID 1
		18	Cable ID 2
		19	N/C
		20	N/C
		21	TE Module (+)
		22	TE Module (+)
		23	N/C
		24	TE Module (-)
		25	TE Module (-)



WARNING

The output terminals of the LDT-5910C or LDT-5940C should never be shorted together or loaded with less than 0.1 Ω . Doing so may result in damage to the instrument.

Analog Control Input: An isolated BNC connector is located on the rear panel of the LDT-5910C and LDT-5940C provides the capability to adjust the temperature setpoint by applying a voltage signal. The LDT-5910C and LDT-5940C can accept a signal from -5 V to +5 V, with a gain of 2 °C/V and bandwidth of 5 Hz. This feature is useful in applications requiring sweeping of the temperature without using GPIB or USB remote interface.

Interlocks: The LDT-5910C and LDT-5940C have normally open and normally closed interlock contacts. The interlock will change states from the “powered off” condition when the output is enabled and will change back when the output is disabled; including any error condition that disables the output.

External Fan Control: The LDT-5910C and LDT-5940C feature the ability to control an external fan through either the 15-pin DSUB connector (5910C) or the 25-pin DSUB connector (5940C). This circuit can provide up to 500 mA and may be controlled from 1 to 12 Vdc. The circuit will automatically increase the voltage to 12 Vdc start a fan from a stopped condition and will regulate to the desired voltage once more than 20 mA is drawn.

Pseudo 4-Wire Measurements: The LDT-5940C offers a pseudo 4-wire measurement feature which helps to minimize errors induced by cable resistance both in thermistor/RTD sensor modes as well as on the output terminals. This feature is enabled by connecting the appropriate ‘sense’ terminals and is disabled by leaving them disconnected. This feature is not available in the LDT-5910C.

Front Panel Operation

This section describes the fundamentals of operation for the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers. The order of descriptions will follow the normal progression of how the user would typically configure the instrument for use for the first time.



Figure 2.1 – Front Panel Display

Power On / Off

The POWER button applies power to the LDT-5910C or LDT-5940C and starts the power up sequence described above.

Adjust Knob and Enable Button



The ADJUST knob and ENABLE button is located on the upper right side of the LDT-5910C and LDT-5940C front panel. It is used to change the setpoints, enter parameter values, enter the GPIB address, enter Save or Recall bin numbers or enter instrument calibration data. The ENABLE button indicates the two modes of operation of the knob: Disabled (LED off) and Enabled (LED on).

Setup

SET Button – Allows the user to adjust settings under PARAM, RECALL and STORE. The SET button will allow the user to select each menu item and a second SET press will allow the user to adjust the parameter. When a parameter is being adjusted, the units will flash at a constant frequency. To return to the main menu, the sub menu will contain one option that reads “Return <SET>.”

PARAM Button – Uses a menu system for temperature controller setup functions including Limits, Sensor, Sensor Calibration Constants, External Fan Control, Cable Resistance, Analog Input, GPIB Address, and Display Brightness. The SET button selects each menu item and a second SET press allows the user to adjust each parameter. The ADJUST knob can be used to cycle through and select or modify the following parameters:

Limits: The Limits menu allows the user to select and modify the temperature, current, and sensor upper and lower limits

- Temperature High / Low Limits
- Current Positive / Negative Limits
- Sensor High / Low Limits

Depending on the sensor selected, the user can configure high and low limits for resistance, current or voltage.

Sensor: The Sensor parameter allows the user to select the type of sensor for the application: Thermistor, RTD, IC-V, or IC-I. For more information on temperature sensors see the “Sensor Options” later in this chapter.

- Thermistor (100 μ A, 10 μ A, Auto Ranging, Linearized)
- RTD (1 mA, 2.5 mA)
- IC – Current
- IC - Voltage

Sensor Calibration Constants: The calibration constants menu allows the user to enter sensor constants for thermistor, current and voltage IC, and RTD. For more information see the “Sensor Options” later in this chapter.

External Fan Control: Allows the user to enable or disable the external fan. The user can also set the voltage applied to an external fan.

Cable Resistance: To increase the accuracy of the TEC voltage measurement at higher currents the user can enter a cable resistance. The value entered for cable resistance should be equal to the round trip resistance between the temperature controller and the load. If the wiring is identical on both sides of the connection, as it is with ILX cables, this value is double the resistance value measured between the temperature controller and the load. The 4-wire capability of the LDT-5940C may be used instead if using a cable that supports this feature. Cable resistance should be set to 0.000 Ω when using 4-wire capability.

Analog Control Input: Enables and disables the analog input feature, for optimal stability if a signal is not applied to the input the analog control input should be disabled.

GPIB Address: Adjust the GPIB address from 1 to 30 using the ADJUST knob.

Display Brightness: Adjust the display brightness from 1 to 10 using the ADJUST knob.

STORE Button – Stores instrument parameters for control mode, setpoint, limits, sensor type, calibration constants, and PID values for bins numbered 1 – 10.

RECALL Button – Recalls instrument parameters for control mode, setpoint, limits, sensor type, calibration constants, and PID values for bins numbered 1 – 10. Recall bin 0 will reset all parameters to the factory defaults.

Non-volatile memory is used for saving the instrument parameters. When a store operation is performed, all of the current instrument parameters are stored to a "bin" number (1 - 10). When that "bin" number is recalled, the instrument configuration is recalled to the stored values.

To enter the STORE/RECALL mode, press either the STORE or RECALL button which will display the current "bin" number in the bottom of the screen. The current "bin" number will be flashing and the ADJUST knob can be used to select a new "bin". The store or recall operation is performed when the SET button is pressed. If the SET button isn't pressed after three seconds the LDT-5910C and LDT-5940C will time out and the new "bin" number will not be stored or recalled.

PID Control

SELECT Button – In PRESET mode, pressing SELECT displays the selected preset gain. In MANUAL mode, pressing SELECT displays the last PID values used and in AUTO-TUNE mode, pressing SELECT displays the auto-tuning method implemented. Pressing SELECT repeatedly or using the ADJUST knob cycles through the presets and PID values.

SET Button – In PRESET mode, pressing SET selects the preset gain range on the display. In MANUAL mode, pressing SET allows the user to adjust the value on the display. SET in the AUTO-TUNE mode starts the auto-tune procedure.

MODE Button –Cycles through PRESET, MANUAL and AUTO-TUNE modes. The selected mode is indicated by an illuminated LED. The output will not be disabled if the user changes the PID Control Mode.

Preset: The user can select one of the preprogrammed gain ranges by first selecting the PRESET LED using the MODE button then pressing the SELECT button or ADJUST knob to display the correct preset gain for the thermal load and pressing the SET button to select the gain. The LDT-5910C and LDT-5940C implements the original gain ranges of the LDT-5910B (Gain 1, 3, 10, 30, 100, and 300). Presets have also been implemented for specific ILX Lightwave mounts. When a preset has been selected for a mount, the LDT-5910C and LDT-5940C will set the PID values, sensor type, and current limits. The following mounts are compatible with the LDT-5910C and LDT-5940C: LDM-4405, LDM-4407, LDM-4409, LDM-4412, LDM-4980, and LDM-4990.

Manual: In MANUAL mode the user can adjust the PID values or select one of the preset PID values to load into the manual adjust (note: if the user adjusts the preset PID value loaded into manual PID adjust the change will not permanently affect the preset PID value). To manually adjust the PID values first select the MANUAL LED by pressing MODE, then press SELECT to change between P, I, and D. To adjust the PID value, press SET; to move to the next value press SELECT.

To load a preset PID value use the SELECT button to cycle to the "Adjust Preset" screen, and then press the SET button, then using the SELECT or ADJUST knob display the preset PID that you want to load. Once the correct preset is displayed press the SET button to load the values.

Auto-tune – The auto-tune mode will calculate a thermal system's PID coefficients through an iterative PID temperature control process. To enter the auto-tune mode first press MODE until the AUTO LED is illuminated, and then SET to begin the auto-tune procedure. When the LDT-5910C and LDT-5940C successfully completes the auto-tune the instrument will revert back to MANUAL and the calculated PID values will overwrite the current PID values in MANUAL mode. If the auto-tune process fails an error will be displayed on the screen. For more information on the auto-tune process see **Appendix B**. Additional auto-tune methods may be available in the future via a firmware upgrade, for more information contact sales at 800-459-9459 / sales@ilxlightwave.com.

There are limitations to the auto-tune feature. Any of the following will cause the auto-tune algorithm to fail:

- Thermal systems requiring the proportional term to be less than 0.5
- Noisy temperature measurements
- Reaching any output off enable condition (such as temperature or voltage limits) during the auto-tune operation.

If the auto-tune algorithm fails for a particular thermal system, it may be necessary to modify the PID coefficients manually.

Mode

SELECT Button – Selects constant temperature, constant sensor and constant current mode. The selected mode is indicated by an illuminated LED. The output is disabled when the control mode is changed.

ON Button – Enables and disables the output. An enabled output is indicated by an illumined LED. A disabled output is indicated by a dark LED.

- TEMP – Controls the LDT-5910C or LDT-5940C to a constant temperature
- I TE – Sets the LDT-5910C or LDT-5940C to output a constant current
- R SNSR – Controls the LDT-5910C or LDT-5940C to a constant sensor value
- HEAT – Illuminated when positive current is flowing
- COOL– Illuminated when negative current is flowing
- I LIMIT – Illuminated if the LDT-5910C or LDT-5940C has reached the user defined current limit.

Display

The large 7-segment LED displays the measured value in the selected operating mode. When the setpoint is being adjusted, the 7-segment LED display will show “set” after the dimension and revert back to reporting the measured value after the three second timeout. The dot matrix display, at the bottom of the screen, cycles through available measurement and mode setpoint. The available measurement and setpoint parameters are listed under General Operation Procedures.

The measured values are indicated by an equal sign, as in Figure **2.2 a**, and the setpoint values are indicated by a colon sign, as in Figure **2.2 b**.



Figure 2.2 a – The measured current



Figure 2.2 b – The setpoint current

LEFT Button – Cycles through available measurement and setpoint parameters that can be displayed in the left hand side of the display.

RIGHT Button – Cycles through available measurement and setpoint parameters that can be displayed in the right hand side of the display.

ADJUST LED – Indicates the status of the ADJUST knob: an illuminated LED means that the knob is enabled and a dark LED means that the knob is disabled.

Error Indicators

The LDT-5910C and LDT-5940C indicate operational errors on the measurement display with an error code. A complete list of error codes can be found in Chapter 5.

General Operating Procedures

The discussion below presents guidelines for operation as well as some common operating procedures. Remote operations are discussed in the next chapter.



The output terminals of the LDT-5910C or LDT-5940C should never be shorted together or loaded with less than 0.1 Ω . Doing so may result in damage to the instrument.

Warm-Up and Environmental Considerations

To achieve the rated accuracy, allow the LDT-5910C or LDT-5940C to warm-up for at least one hour before use. Operate the controller within the environmental limits specified in Chapter 1. The best accuracy is achieved near the calibration temperatures.

General Guidelines for Sensor Selection and Safety Limits

This section presents some guidelines to assist in selecting the optimal settings for your application.

Sensor Options

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers can measure temperature through a variety of sensor options; thermistors, IC sensors (IC-I, IC-V) or RTDs.

THERMISTOR – When a thermistor sensor is selected, the LDT-5910C and LDT-5940C measures temperature based on a negative temperature coefficient (NTC) thermistor. An NTC thermistor is a device whose resistance decreases as its temperature increases. The controller provides a sense current (100 μ A or 10 μ A) through the thermistor which results in a voltage across the thermistor. This voltage is used as a feedback signal by the LDT-5910C and LDT-5940C digital control loops to maintain a constant temperature. The thermistor should be connected across the Sensor+ and Sensor- pins (pins 7 and 8).

In constant temperature mode, the quantity that is maintained constant by the controller is the sensor resistance. In constant temperature mode (T), the LDT-5910C and LDT-5940C convert the temperature setpoint to a thermistor resistance setpoint using user defined constants.

The Steinhart-Hart equation is used to convert a temperature to a resistance for thermistor sensors. The equation describes the non-linear resistance versus temperature characteristics of typical thermistors. Calibrating a thermistor consists of measuring its resistance at various temperatures and fitting this measured data to the Steinhart-Hart equation. The resulting coefficients C1, C2, and C3 effectively describe the thermistor for a specific temperature range. For more information about the Steinhart-Hart equation, see ILX Lightwave Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

To measure the precise temperature of a load, you must use a calibrated sensor. For example, when using a thermistor, enter its Steinhart-Hart coefficients C1, C2, and C3 into the temperature controller. If the exact temperature is not crucial (within $\pm 1.5^\circ\text{C}$) and you are using a 10 k Ω thermistor, use the default constants provided by the LDT-5910C and LDT-5940C.

Thermistor resistance changes with temperature. The LDT-5910C and LDT-5940C supplies constant current, either 10 μA or 100 μA , through the thermistor so that a temperature change results in a voltage change across the thermistor. This voltage change is sensed by the instrument and fed back to the control loop. The supply current selection depends on the thermistor operating temperature range and the required temperature resolution. A general rule of thumb for a 100 k Ω thermistor is to use the 10 μA range for temperatures between -30°C and $+30^\circ\text{C}$ and for 10 k Ω thermistor the 100 μA range for temperatures between 10°C to 70°C . Select the thermistor sense current of 10 μA or 100 μA in the front panel PARAM menu. Using 10 μA as the thermistor current allows you to use a maximum thermistor resistance of 450 k Ω . The 100 μA setting allows a 45 k Ω maximum.

The LDT-5910C and LDT-5940C have the ability to select the sensor current range based on the resistance of the measurement and will automatically switch between the 10 μA or 100 μA . Thermistor auto range can be selected under the SENSOR menu in PARAM.

To ensure proper thermistor current and thermistor selection, certain principles must be considered:

- To ensure measurement accuracy, the voltage across the thermistor must not exceed 6 V.
- To improve control responsiveness and accuracy, the thermistor voltage variations that result when the load temperature deviates from the setpoint must be as large as possible. The importance of maximizing voltage variation is shown in Figure 2.3, which shows resistance as a function of temperature for a thermistor. The values shown were selected for simplicity in this example, and may not reflect real thermistor values.

In the example shown in Figure 2.3, the thermistor resistance is 25 k Ω at 20°C . Deviations of one degree at 20°C cause a resistance variation of about 2 k Ω . If using the 10 μA setting, there is 20 mV of feedback to the control circuit. Using the 100 μA setting provides 200 mV of feedback. The larger feedback signal means that the temperature is more precisely controlled.

Notice also that the lower slope of the curve at the higher temperatures results in a smaller feedback signal. It may be necessary, if you are controlling to higher temperatures, to use a thermistor with a different curve.

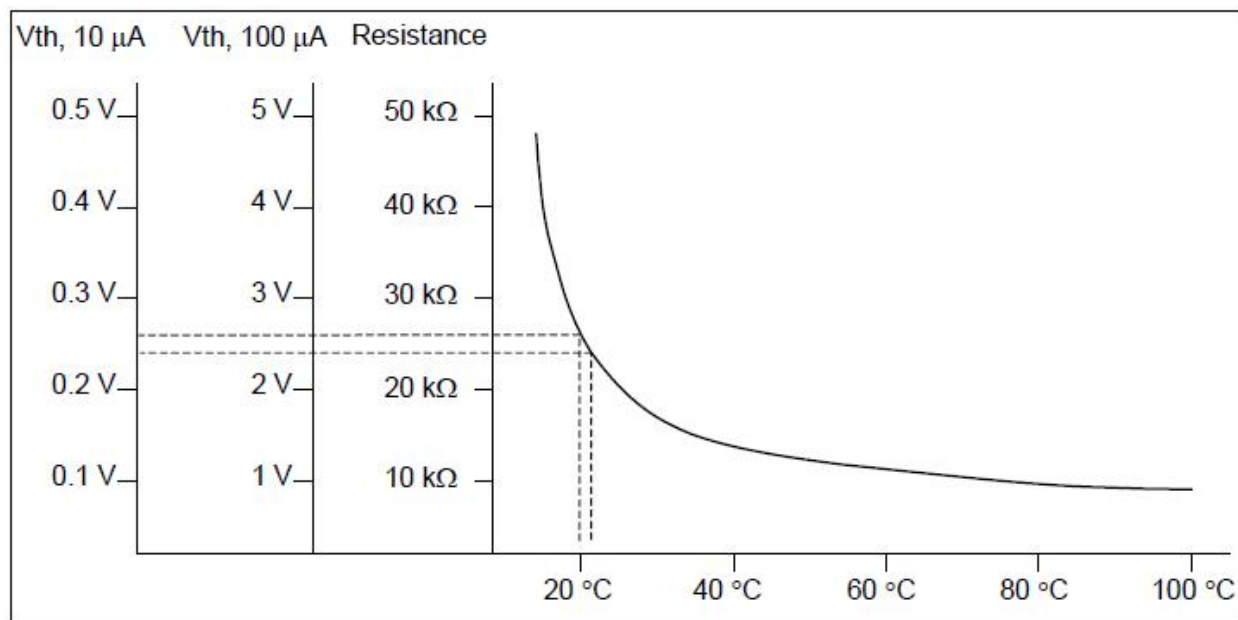
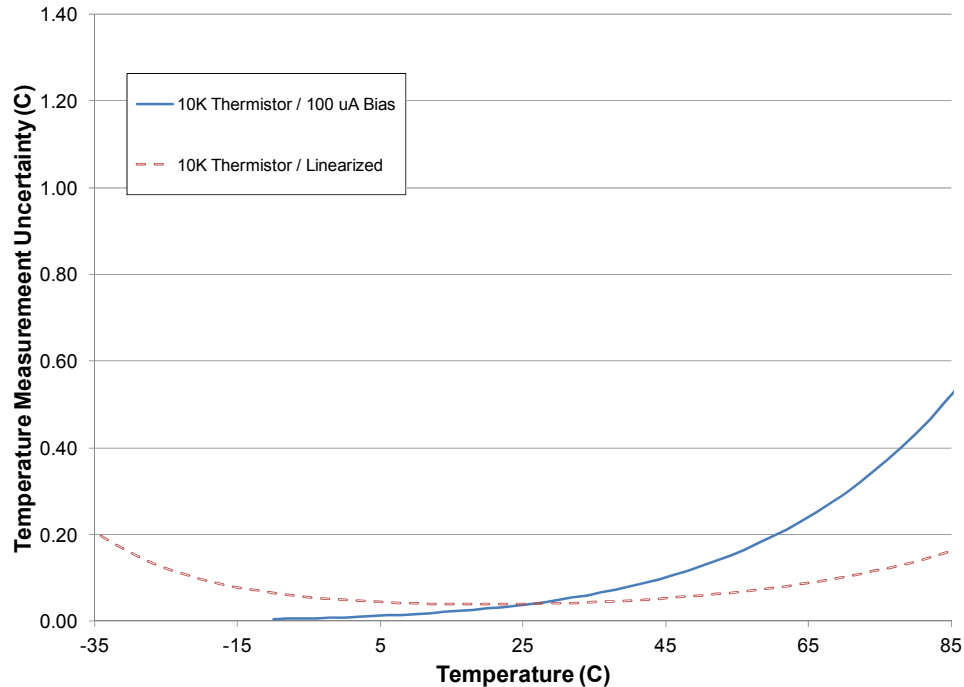


Figure 2.3 - Example Thermistor Resistance vs. Temperature

LINEARIZED THERMISTOR - The linearized thermistor mode of the LDT-5910C and LDT-5940C may be used when an expanded range of temperature operation is required but when ranging discontinuities are unacceptable. The linearized thermistor mode provides ± 0.2 °C accuracy over a temperature range of -15 °C to 65 °C and ± 0.1 °C accuracy over a range of 5 °C to 35 °C without requiring the calibration of two sensors and without the discontinuity that may arise due to ranging in the auto-ranging thermistor mode.



IC-I SENSORS – When an IC-I sensor is selected, the LDT-5910C and LDT-5940C measures temperature based on the current passed through the sensor. An example of an IC-I sensor is the Analog Devices AD590. This device delivers 1 $\mu\text{A/K}$ or approximately 298 μA at 25 $^{\circ}\text{C}$. The (+) terminal of the transducer should be connected to the Sensor+ pin and the (-) terminal should be connected to Sensor-. The nominal slope for the AD590 is 1 $\mu\text{A/K}$ and the offset is nominally 0 μA but both can be adjusted to calibrate your particular sensor by entering the PARAM menu.

The sensor will have approximately 9 V across it at 25 $^{\circ}\text{C}$ but will vary over the temperature range. In IC-I sensor mode, the LDT-5910C and LDT-5940C have a sensor current limit of 600 μA , which is approximately 325 $^{\circ}\text{C}$.



For IC-Current sensors used with the LDT-5940C the 4-wire sensor measurements (pins 1 and 2) should not be connected. The use of the 4-wire sensor will cause inaccurate sensor measurements.

IC-V SENSORS – When an IC-V sensor is selected the LDT-5910C and LDT-5940C measures temperature based on the voltage across the sensor. An example of an IC-V sensor is the National Semiconductor LM335A. This device delivers 10 mV/K or approximately 2.98 V at 25 $^{\circ}\text{C}$. The (+) terminal of the transducer should be connected to the Sensor+ pin and the (-) terminal should be connected to Sensor-. The nominal slope for the LM335A is 10 mV/K and the offset is nominally 0 mV but both can be adjusted to calibrate your particular sensor by entering the PARAM menu.

The sensor will have approximately 1 mA of current through it at all times. In IC-V sensor mode, the LDT-5910C and LDT-5940C have a sensor voltage limit of 6 V, which is approximately 325 °C.

RTD SENSORS – When an RTD sensor is selected, the LDT-5910C and LDT-5940C measures temperature based on the resistance. An example of an RTD sensor is the Xian Diamond USA T2001SDL. This device has a positive slope and a nominal resistance at 0 °C of 100 ohms. Two wire RTDs should be connected across the Sensor+ and Sensor- pins (pins 7 and 8).

The resistance versus temperature function for typical platinum RTDs is accurately modeled by the Callendar-Van Dusen equation, as shown below.

$$R_T = R_0 (1 + AT + BT^2 + 100CT^3 + CT^4)$$

where:

R_0 = Resistance (Ω) at 0 °C
 R_T = Resistance (Ω) at temperature T (°C)
T = Temperature in °C

The A, B, and C, are derived from resistance measurements at 0 °C (R_0), 100 °C (R_{100}) and 260 °C (R_{260}), and are defined as follows:

$$A = \alpha + (\alpha * \delta)/100$$

$$B = (-\alpha * \delta)/100^2$$

$$C_{T<0} = (-\alpha * \beta)/100^4$$

where: $\alpha = R_{100} - R_0 / 100 * R_0$
 β = Constant for T < 0 °C
 $\delta = R_0 * (1 + \alpha * 260) - R_{260} / 4.16 * R_0 * \alpha$

For temperatures greater than 0 °C, the LDT-5910C and LDT-5940C controller derives the temperature by solving the following quadratic equation:

$$T = \frac{-R_0 A \pm \sqrt{R_0^2 A^2 - 4R_0 B (R_0 - R_T)}}{2R_0 B}$$

These sensor coefficients (A, B, C and R_0) are required for the LDT-5910C and LDT-5940C to accurately report the temperature when utilizing an RTD sensor. Where R_0 is the resistance of the RTD at 0 °C. Typical RTDs have a nominal resistance (R_0) of 100 Ω or 1000 Ω .

Common Callendar-Van Dusen constants are listed below and are used as default values in the LDT-5910C and LDT-5940C.

- $A = 3.908 \times 10^{-3}$
- $B = -5.775 \times 10^{-7}$
- $C = -4.183 \times 10^{-12}$

For optimal accuracy and stability, the 1 mA current source should be selected for RTD sensors with resistance of 200 Ω to 1500 Ω and the 2.5 mA range should be used with resistance of 1 Ω to 200 Ω . In general, the change in resistance per change in temperature is much lower for a typical 100 Ω RTD than that of a typical 10 k Ω thermistor. The proportional and integral terms for the PID loop must be increased appropriately when using an RTD sensor for optimal setting time and stability.

Safety Limits

TEC modules may be damaged by excessive current, so module manufacturers typically specify a maximum safe operating current for their module. The LDT-5910C and LDT-5940C provides a current limit feature that allows you to set the maximum current that the controller supplies.

It is normal for the controller to operate at the current limit, especially when the load temperature is far from the setpoint. The current limit LED will display on the front panel when the controller is in a current limit condition.

If the heatsink is too small for the application, it eventually becomes heat-saturated where in the heatsink can no longer dissipate the heat being generated. When the heatsink becomes saturated, the TEC current increases in an attempt to cool the load. The additional current creates more heat that cannot be dissipated and subsequently, more TEC current is applied. This situation is referred to as *thermal runaway* and can cause a load and temperature controller to become damaged.

To help avoid damage caused by thermal runaway, the LDT-5910C and LDT-5940C Thermoelectric Temperature Controller provides a high-temperature limit setting. When the load temperature exceeds the temperature limit, the LDT-5910C and LDT-5940C turns off the TEC current and generates an error on the dot matrix display.

Constant Temperature Mode Operation

1. Plug the LDT-5910C or LDT-5940C into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDT-5910C or LDT-5940C. The output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off
3. Press **MODE** until the TEMP LED is selected
4. Press **PARAM** to adjust the applicable limits, sensor type, calibration constants, GPIB address, display brightness and external fan voltage
5. Adjust the setpoint by enabling the ADJUST knob and enable the output
6. The user can display measured voltage, current, or sensor value or the temperature setpoint in either the left or right side of the display by pressing the **LEFT** and **RIGHT** display buttons

Constant Sensor Mode Operation

1. Plug the LDT-5910C or LDT-5940C into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)

2. Turn on the LDT-5910C or LDT-5940C. The output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off
3. Press **MODE** until SNSR is selected
4. Press **PARAM** to adjust the applicable limits, sensor type, calibration constants, GPIB address, display brightness and external fan control
5. Adjust the setpoint by enabling the ADJUST knob and enable the output
6. The user can display measured voltage, current, or temperature or the sensor setpoint in either the left or right side of the display by pressing the **LEFT** and **RIGHT** display buttons

Constant Current Mode Operation

1. Plug the LDT-5910C or LDT-5940C into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDT-5910C or LDT-5940C. The output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off
3. Press **MODE** until ITE is selected
4. Press **PARAM** to adjust the applicable limits, sensor type, calibration constants, GPIB address, display brightness and external fan control
5. Adjust the setpoint by enabling the ADJUST knob and enable the output
6. The user can display measured voltage, sensor value, or temperature or the current setpoint in either the left or right side of the display by pressing the **LEFT** and **RIGHT** display buttons

Resistive Heater Mode Operation

1. Plug the LDT-5910C or LDT-5940C into an AC power source supplying the correct mains voltage and frequency for your instrument (refer to the rear panel for the correct ratings)
2. Turn on the LDT-5910C or LDT-5940C. The output will be disabled at power up and the unit will automatically configure its parameters to the state which existed when the power was last shut off.
3. Press **MODE** until TEMP LED or SNSR LED is selected
4. Press **PARAM** then select **LIMITS** and adjust **I-** to maximum current limit for your resistive heater then select **I+** and set to 0 amps (by setting the limit to zero when the LDT-5910C or LDT-5940C attempts to cool the load the output will be limited to 0 amps)
5. Press **PARAM** to adjust the applicable limits, sensor type, calibration constants, GPIB address, display brightness and external fan control
6. Adjust the setpoint by enabling the ADJUST knob and enable the output
7. The user can display measured voltage or current and depending upon the mode (constant TEMP or SNSR) can display either the measured temperature (constant SNSR) or sensor (constant TEMP) or the setpoint temperature (constant TEMP) or sensor (constant SNSR) in either the left or right side of the display by pressing the **LEFT** and **RIGHT** display buttons

Chapter 3:

Remote Operation

This chapter is an overview of the remote operation of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controller.

- ✓ Fundamentals of Remote Operation
- ✓ Command Syntax
- ✓ Command Tree Structure
- ✓ Status Reporting

Test and measurement equipment with remote operation capability will generally communicate through either GPIB or USB interfaces. GPIB (General Purpose Interface Bus) is the common name for *ANSI/IEEE Standard 488.2 1987*, an industry standard for interconnecting test instruments in a system. USB (Universal Serial Bus) is the common serial communication protocol used by most computers for relatively fast communication. Everything that can be done from the front panel can also be done remotely, and in some cases, with more flexibility. For instance, in remote mode, there is access to functionality and modes not available from the front panel, such as commands that will increment (Temperature UP) or decrement (Temperature DOWN) the temperature setpoint by a predefined step value. The following sections explain the fundamentals of operating the LDT-5910C and LDT-5940C Thermoelectric Temperature Controller remotely through either the GPIB or USB computer interface.

GPIB Address

The talk and listen addresses on the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers are identical. This GPIB address is read locally by pressing the PARAM button until the GPIB Address is displayed on the dot matrix display. The driver comes from the factory configured with the GPIB address set to 1. You can change the LDT-5910C's and LDT-5940C's GPIB address locally (via the front panel). A procedure for changing the address can be found in the section changing the GPIB Address.

Basic GPIB Concepts

The information in this section is normally not necessary to successfully operate the LDT-5910C and LDT-5940C through its GPIB interface because the host computer's GPIB controller usually handles the details. However, it is a useful introduction to understanding GPIB.

Data and Interface Messages

GPIB devices communicate with each other by sending data and interface messages. Data contains device-specific information such as programming instructions, measurement results, and instrument status. Each device has an address number, and ignores all data traffic not addressed to it. Depending on its content, data is often called a "device dependent message" or a "device dependent command". Interface messages manage the bus, with functions such as initializing the bus and

addressing or un-addressing devices. In addition, some individual bus lines are designated for this purpose.

Talkers, Listeners, and Controllers

Every GPIB system consists of one or more “talkers” and “listeners”, and often at least one “controller”. Talkers supply data while listeners accept data. A system can consist of simply a talker and listener, for example a meter connected to a datalogger or chart recorder. Controllers designate talkers and listeners. A controller is necessary when the active talkers or listeners must be changed. When the controller is a computer, it often also designates itself as a listener so it can collect data from designated talkers.

If there is more than one controller, only one can be the Controller in Charge (CIC). Control can be passed from one computer to another. In a multiple controller system, there can be one “System Controller” capable of asserting control (becoming CIC).

GPIB Cable Connections

Standard GPIB connectors can be connected together (stacked) allowing the system to be configured linearly, or in a star configuration.

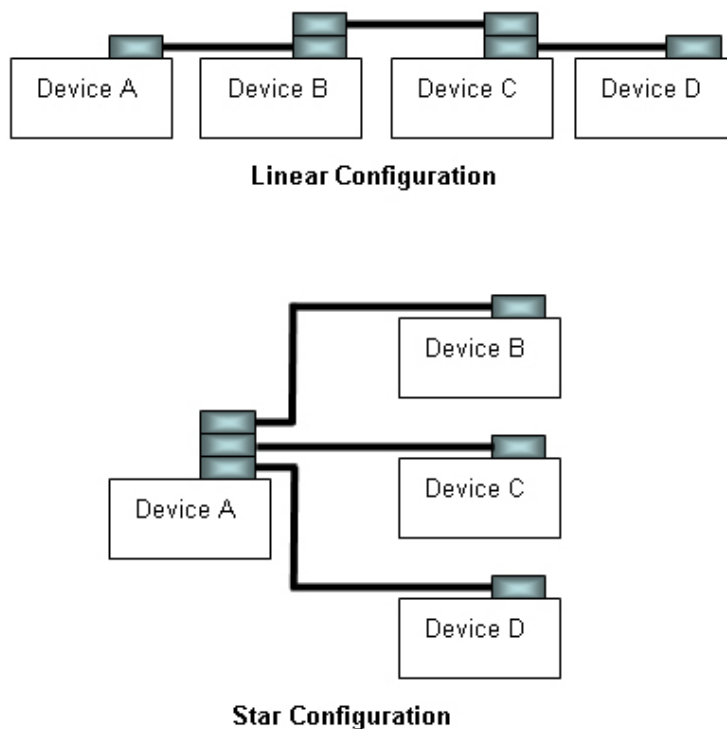


Figure 3.1 – GPIB Cable Connection

The GPIB Connector

The standard GPIB connector consists of 16 signal lines in a 24-pin stackable connector. The extra pins are used to make twisted pairs with several of the lines. There are eight data input/output lines, three handshake lines, and five interface management lines.

Eight data I/O (DIO) lines carry both data (including device dependent commands) and interface messages. The ATN interface management line determines whether these lines contain data or interface messages.

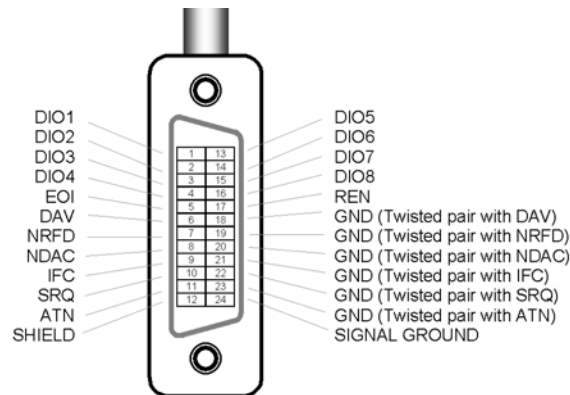


Figure 3.2 – GPIB Connector

Three handshake lines ensure that all data and messages are reliably transferred:

- NRFD (not ready for data) indicates whether a device can receive the next byte of data or message.
- NDAC (not data accepted) indicates whether a receiving device has accepted a byte of data or message.
- DAV (data valid) indicates that the signal levels on the data lines are stable and available for the receiving device(s) to accept.

Five interface management lines control the flow of information:

- ATN (attention) is set by the controller in charge to define the I/O lines for data or interface messages.
- IFC (interface clear) is set by the system controller to initialize the bus and assert itself as controller in charge.
- REN (remote enable) is set by the controller to place addressed devices into remote or local (front panel) control mode.
- SRQ (service request) can be set by any device in the system to request service from the controller.
- EOI (end or identify) is used by talkers to identify the end of a message.

Reading the GPIB Address

Before operating the LDT-5910C or LDT-5940C remotely, its GPIB address must be known. Simply press the PARAM button until GPIB Address is displayed in the display. The factory default address is "GPIB ADDRESS: 1".

Changing the GPIB Address

Every device on the GPIB bus must have a unique address. If it is necessary to change the address, press the PARAM button until the GPIB address is displayed. Then press the SET button and adjust the knob until the desired address value is shown. When the display times out, the new GPIB address will be stored in nonvolatile RAM. The allowable address range is 1 – 30 for primary GPIB addressing. It is not recommended that zero be used for an address as that is typically reserved for the GPIB controller installed in the computer. Extended GPIB addressing is not implemented.

Basic USB concepts

Universal Serial Bus (USB) is a specification to establish communication between devices and a host controller, which has effectively replaced a variety of earlier interfaces such as serial and parallel ports. There are three USB standards available, including USB 1.1, USB 2.0, and USB 3.0. Our device is designed to conform to the USB 2.0 standard and USBTMC 488 substandard. USB cables use 4 lines - Power, Ground and a twisted pair differential +/- data lines. The USB connectors are designed so that power and ground are applied before the signal lines are connected. When the host powers up it performs the enumeration process by polling each of the Slave devices in turn (using the reserved address 0), assigning each one a unique address and finding out from each device what its speed is and what type of data transfer it wishes to perform. The enumeration process also takes place whenever a device is plugged into an active network. The connectors design along with the process of enumeration and a lot of host software allows devices to be described as "Plug-and-Play".

When the USB device is enumerated and gets an address from the host, it presents the host with information about itself in the form of a series of descriptors. The device descriptor tells the host the vendor and the product ID. The configuration descriptors offer a power consumption value and a number of interface descriptors. Each of these interface descriptors define a number of endpoints, which are the sources and destinations for data transfers. The endpoint descriptors provide the following detail transfer type: bulk, interrupt, isochronous, direction, packet sizes, bandwidth requirement and repeat interval.

In USB communication, a typical transaction consists of a number of packets - a token indicating the type of data that the host is sending or requiring, the data and in some cases an acknowledgement. Each packet is preceded by a sync field and followed by an end of packet marker. These transactions are used to provide four basic data transfer mechanisms, including control, interrupt, bulk, and isochronous types.

USBTMC stands for **USB Test and Measurement Class**. USBTMC is a protocol built on top of USB that allows GPIB-like communication with USB devices. From the user's point of view, the USB device behaves just like a GPIB device. For example, you can use VISA Write to send the *IDN? Query and use VISA Read to get the response. The USBTMC protocol supports service request, triggers and other GPIB specific operations. USBTMC allows instrument manufacturers to upgrade the physical layer from GPIB to USB while maintaining software compatibility with existing software, such as instrument drivers and any application that uses VISA.

Changing Between Local and Remote Operation

Sending a command over the GPIB or USB bus automatically puts the instrument in Remote mode. The Remote indicator identifies when the controller is in remote operation mode. When the instrument is in Remote mode, all front panel controls are disabled except for the Local button. Pressing the Local button returns the instrument to Local control mode unless the Local Lockout state has been activated by the host computer. Local Lockout disables all front panel controls, including the Local button, until this condition is changed by the host computer. When the instrument is placed in Local Lockout Mode by the host computer, the Remote indicator will light on the VFD display.

GPIB vs. USB Communication

When using the USB interface, the remote GPIB command set is fully operable. Command syntax does not vary between communication protocols. However, the commands which affect GPIB hardware operation will not be useful. For example, “*SRE” may be sent via USB but service request (SRQ) via GPIB would not be visible since USB has no hardware to support it. This is because SRQ is a function of the GPIB interface hardware and is not available via USB.

All commands received by the USB interface are acknowledged by the instrument transmitting “Ready” when the command operation is complete. Queries are acknowledged by the specific query response message. Multiple commands/queries separated by semicolons and issued as one command string are only acknowledged with a “Ready” response if the entire command string contains no queries. (See the Command Separators section later in this chapter for additional details.) The LDT-5910C and LDT-5940C terminates all RS-232 transmitted responses with <CR><LF> (Carriage Return – Line Feed) characters. The LDT-5910C and LDT-5940C expect all commands or queries to be terminated with any of the following characters: <CR> (Carriage Return), <LF> (Line Feed), or ASCII 250 character (Hex 0xFA).

Command Syntax

This section describes command syntax and structure. This information must be understood in order to effectively write GPIB control programs. The syntax of GPIB commands follow the rules defined in the IEEE 488.2 standard.

Letters

Any GPIB command or query must contain all of the letters or all of the upper case letters which are shown in the command definition. Upper/lower case does not matter; it is used in this manual to identify optional letters. Some examples of what works and what does not are shown below.

Table 3.1 – Acceptable and Not Acceptable Spelling

ACCEPTABLE	NOT ACCEPTABLE
DISP	DS
DISPlay or DISPLAY	Displa or DISPL

White Space

“White space” is normally the space character (space bar). A single white space must separate a command from its parameters or data. For example:

Table 3.2 – White Space

ACCEPTABLE	NOT ACCEPTABLE
ITE 3.0	ITE3.0

To enhance readability, one or more white spaces may be used before a comma, semicolon, or terminator. Since the computer normally places the terminator at the end of each command string (line), this simply means that an extra space character at the end of the command line works acceptably.

A query has no space between the mnemonic and the question mark. For example:

Table 3.3 – Query Formatting

ACCEPTABLE	NOT ACCEPTABLE
DISPLAY?	DISPLAY ?

Note: Too many consecutive white spaces can overflow the 256-byte data I/O buffer.

Terminators

A program message terminator identifies the end of a command string. These are the valid terminator sequences:

- <NL>
- <^END>
- <NL><^END>

Many computers terminate with <CR><NL><^END> (Carriage Return – New Line – EOI). A carriage return (<CR>) is read as white space.

The LDT-5910C and LDT-5940C terminates its responses with <CR><NL><^END>, unless the TERM command is used to change it.

If problems are encountered with GPIB communications, the terminator string can sometimes be the cause. Refer to the computer's GPIB controller manual for information on configuring its terminator string.

Command Separators

More than one command may be placed in the same command string if each command is separated by a semicolon. The semicolon can be preceded by one or more spaces. For example:

```
DISPLAY ON;*IDN?;MODE?  
DISPLAY ON ; *IDN?; MODE?
```

Parameters

Some commands require a parameter. The parameter must be separated by at least one white space.

The syntax symbol <nrf value> refers to the flexible numeric representation defined by the GPIB standard. It means that numbers may be represented in integer or floating point form, or in engineering/scientific notation. The IEEE 488.2 standard uses the names NR1, NR2, and NR3 respectively to denote “integer”, “floating point”, and “scientific notation”. For example the number “twenty” may be represented by any of the following ASCII strings:

Table 3.4 – Parameters

NR1	Integer	20	+20
NR2	Floating Point	20.0	+20.0
NR3	Scientific Notation	2.0E+1 2.0e+1	+2.0E+1 +2.0e+1

For more information on these definitions, refer to the IEEE 488.2 standard.

There are no default values for omitted parameters. If a command is expecting a parameter and nothing is entered, an error is generated.

For further clarity in programming, the Boolean values of one (1) and zero (0) may be used or their names as indicated in Table 3.5.

Table 3.5 – Substitute Parameter Values

SUBSTITUTE NAME	VALUE
ON	1
OFF	0
RUN	1
STOP	0

Command Tree Structure

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers device-dependent commands are structured in a tree format as shown in Figure 3.3. Each of the legal paths is shown, followed by its list of path options, followed by the commands themselves. It is recommended that the first-time user begin learning the commands by using the full path notation. Once familiar with the commands, command path shortcuts may be used.

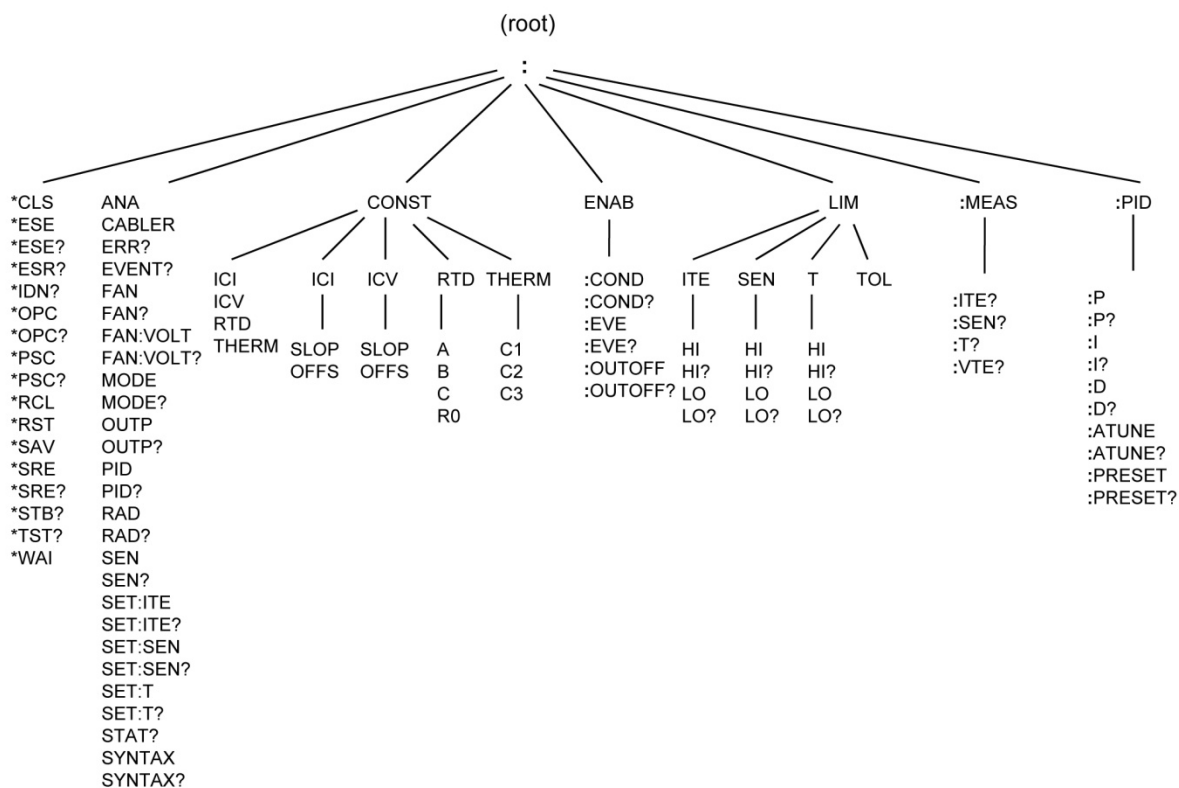


Figure 3.3 - Command Path Structure

Syntax Summary

GPIB commands must contain all of the letters shown in uppercase in the command definition. Optional letters shown in lowercase for some device dependent commands in the command reference (Chapter 4) are useful for clarity, but must be in the correct sequence.

A single white space must separate a command from its parameters or data. White space is normally the space character (space bar). Other control characters are also interpreted as white space. Do not use white space before the question mark in a query command.

If problems are encountered with communications, the terminator string may be the cause. Refer to the GPIB interface (controller) manual for additional information. The instrument accepts <NL>, or <^END>, or <NL><^END> as a command line terminator. Many computers terminate with <CR><NL><^END> (Carriage Return – New Line – EOI). The instrument ignores <CR> (Carriage Return) as white space. The LDT-5910C and LDT-5940C terminates its responses with <CR><NL><^END>.

More than one command may be on the same line (same command string) if the commands are separated with semicolons.

GPIB uses a flexible representation for numeric parameters: integer, floating point, or engineering/scientific notation. There are no default values for omitted parameters.

Some device-dependent GPIB commands are compound commands, in which the first mnemonic opens a path to a set of commands relating to that path. The second mnemonic then defines the actual command.

Following are examples of invalid syntax command strings that will produce errors:

Table 3.6 – Invalid Syntax Command Strings

COMMAND	COMMENT
LIM:ITE HI?	Missing colon
OUT ON INC	Missing semicolon; INC command generates an error.
DIS ?	Space not allowed before question mark. DIS command expected.
T5.4;dis?	Space missing between T command and the parameter value 5.4.

IEEE 488.2 Common Commands

The IEEE 488.2 Common Commands and Queries are distinguished by the “*” which begins each mnemonic. The diagrams below show the syntax structure for common commands, common command queries, and common commands with numeric data required.

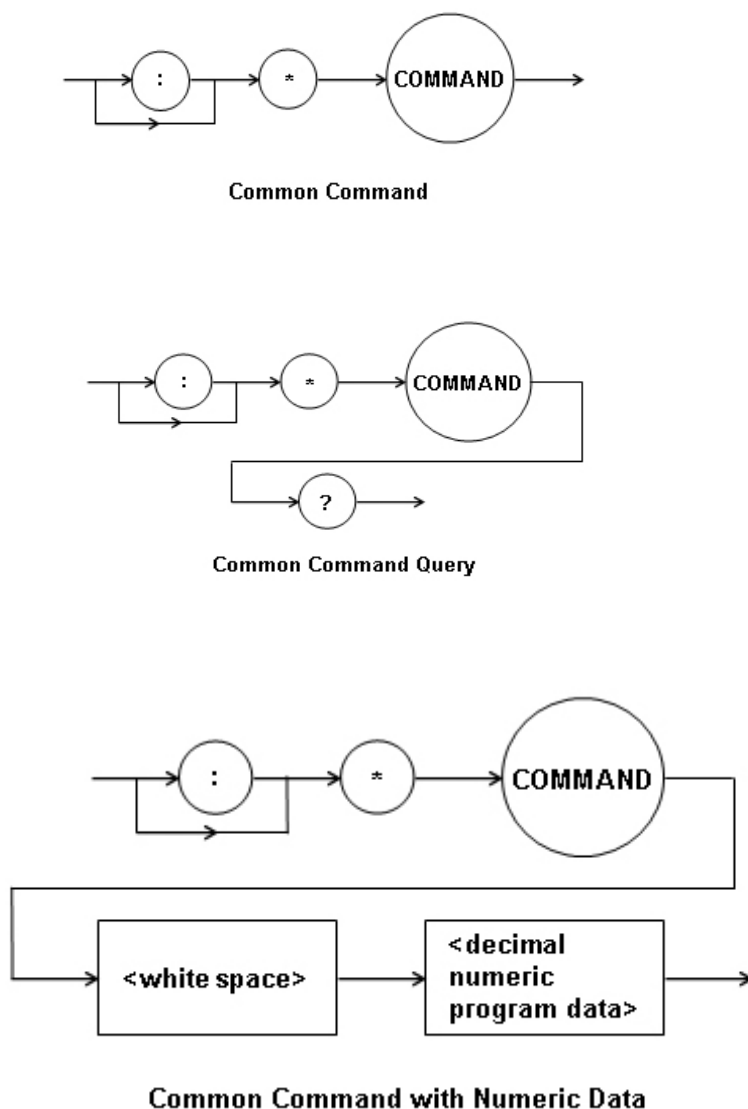


Figure 3.4 – Common Command Diagrams

Numeric data is required with *PSC (1 = on, 0 = off), *RCL (0 – 10, see front panel RECALL function), *SAV (1 – 10, see front panel STORE function), and *ESE (0 – 255, see Figure 3.2 – GPIB connector diagram).

All the IEEE 488.2 Common Commands supported by the LDT-5910C and LDT-5940C are listed below:

Table 3.7 – IEEE 488.2 Common Commands Supported by LDT-5910C and LDT-5940C

*CLS	*ESE	*ESE?	*ESR?
*IDN	*OPC	*OPC?	*PSC
*PSC?	*RCL	*RST	*SAV
*SRE	*SRE?	*STB?	*TST?
*WAI			

See Chapter 4 – Command Reference for descriptions of all commands, including common commands, supported by the LDT-5910C and LDT-5940C.

Status Reporting

This section contains information that is relevant for understanding instrument error and status reporting. It also contains information regarding the use of the instrument status for generating interrupts for interrupt driven programs or subroutines. Understanding the Operation Complete definition for the instrument is useful for program synchronization. The Output Off Register section also contains information on configuring the conditions which force the TEC output off.

Event and Condition Registers

In addition to the required IEEE 488.2 status reporting structure, the LDT-5910C and LDT-5940C remote interface provides Event and Condition Registers for TEC controller operations. The Event Registers are used to report events which occur during the operation of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controller. Events differ from conditions in that events signal an occurrence once, and are not reset until the Event Register is queried or the LDT-5910C or LDT-5940C is powered off. Conditions reflect the current state of the instrument, and therefore may change many times during operation. Querying a Condition Register does not change its contents.

Figure 3.5 shows the status reporting scheme of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers. Each of the registers which may be accessed by a command or query has the appropriate command or query written above or below the register representation. For example, the TEC Condition Register may be queried via the “COND?” or “STATus?” query.

The condition or event registers are logically ANDed with their respective enable registers. These bits are then logically ORed to form a summary message in the status byte for that particular register.

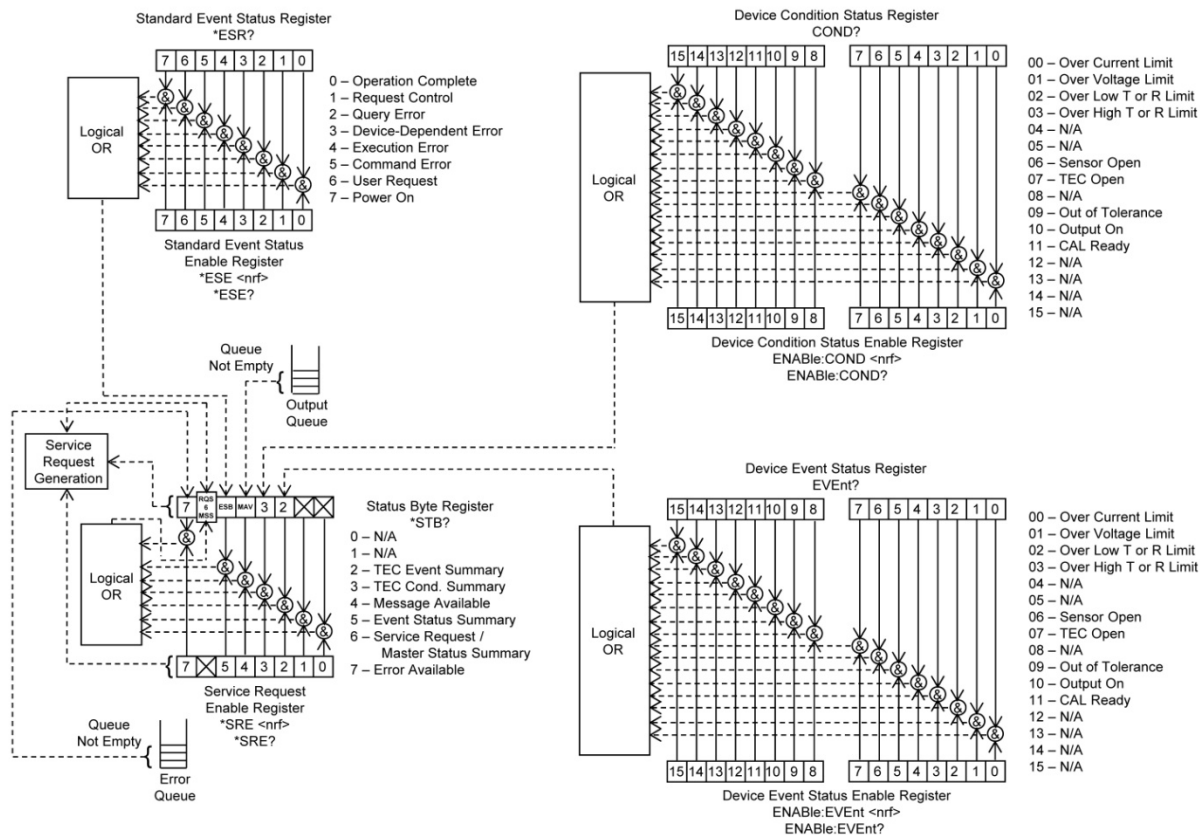


Figure 3.5 – Status Reporting Scheme

Operation Complete Definition

Note that Bit 0 of the Standard Event Status Register contains the status of the Operation Complete flag. Enabling this bit via the *ESE command allows the user to update Bit 5 of the Status Byte. Then, if the SRE mask has Bit 5 set, and the user issues an *OPC command, the SRQ signal will be generated upon completion of the currently processed commands. This may be used to initiate service request routines which depend on the completion of all previous commands.

For example, the user may set the output temperature tolerance so that the temperature is considered to be in tolerance when it is within 0.2 °C of the setpoint for 10 seconds. Then, they may enable an SRQ on Operation Complete (set *ESE 1 and *SRE 5), and have an SRQ handling routine in their software which reads a new measurement after the temperature is within tolerance. This allows the use of the operation complete features of the LDT-5910C or LDT-5940C, without the need for program looping or polling which can tie up the GPIB bus. Operation Complete on the LDT-5910C and LDT-5940C is defined as:

- No operations to the TEC hardware are pending.
- No EEPROM (non-volatile) memory write cycles are in progress.

Note: If the GPIB times out while waiting for a response, either set the GPIB time-out longer or use SRQ-generated interrupts. See the GPIB interface manual for time-out configuration or SRQ programming setup. The *OPC, *OPC?, and *WAI commands should not be used inside a calibration routine.

Output Off Register

The Output Off Enable Register determines which conditions and events can cause the TEC output to be turned off. This register is configured in a manner which is similar to the status reporting registers. However, its output is not reported in the Status Byte Register. Rather, it is directly tied to hardware which controls the output switching. The events and conditions which may be set to cause the TEC output to be turned off are shown in Figure 3.6. The default (factory) settings are shown in Table 3.8. These settings are not affected by the *PSC (Power-On Status Clear) command.

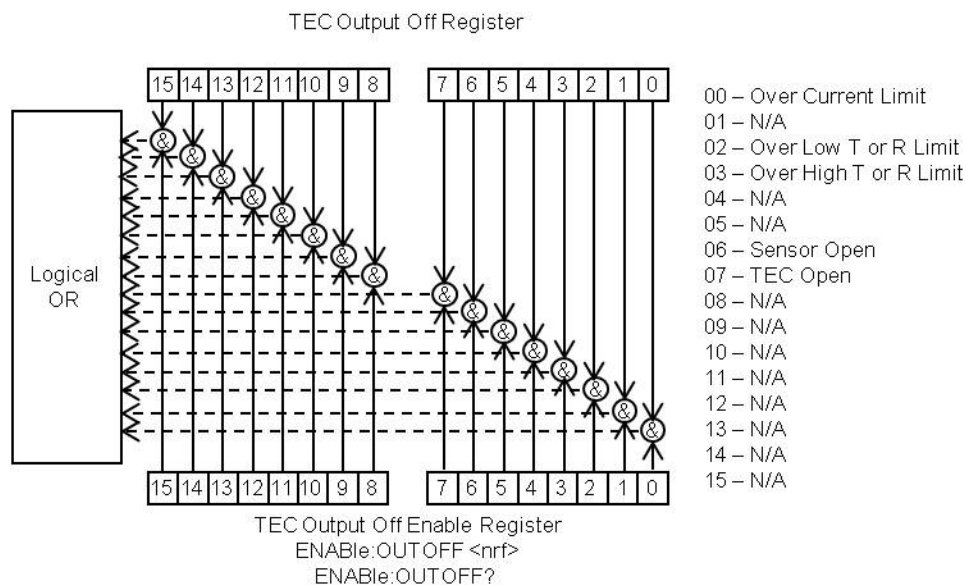


Figure 3.6 – TEC Output Off Register

Table 3.8 – Default Output Off Register Settings Bit Reference

00 – Over Current Limit	08 – N/A
01 – N/A	09 – N/A
02 – Over Low T or R Limit	10 – N/A
03 – Over High T or R Limit	11 – N/A
04 – N/A	12 – N/A
05 – N/A	13 – N/A
06 – Sensor Open	14 – N/A
07 – TEC Open	15 – N/A

Command Timing

This section describes, for each device-dependent command, whether that command is performed in an overlapped or sequential manner. In other words, it states whether the next command may begin while the first is being executed, or if it must wait until the first command is completed before its execution begins. See the Operation Complete Definition earlier in this chapter for conditions about setting the operation complete flag.

Sequential / Overlapped Commands

All device-dependent commands are executed in an overlapped manner: subsequent commands may begin before the current command has completed. Some common commands are sequential; the next command must wait until this command has completed. All device-dependent commands are executed in an overlapped manner. The operation complete flag is set after the conditions outlined in the Operation Complete Definition have been satisfied.

The *WAI (common command) is an example of a sequential command which forces the next command to wait until the no-operation flag is true. This is essentially the same as waiting for the OPC flag to become true, because the no-operations-pending flag is used to set the OPC flag (bit 0 of the Standard Event Status Register).

Commands which change the status of the instrument limits, or change its mode, step value, or status enable registers, will not have their OPC flag set until all current writing to non-volatile memory has been completed. This ensures the OPC flag is never set prematurely.

Query Response Timing

Query responses are evaluated at the time the query request is parsed, and not at the time the response message is sent. In most cases, this does not create a problem since the time between parsing a query and sending its response is small.

Chapter 4:

Command Reference

This chapter is a guide to all of the device-dependent commands for the LDT-5910C and LDT-5940C Precision Thermoelectric Temperature Controllers. This chapter is divided into three parts.

- ✓ Overview of the remote commands
- ✓ List of remote commands in alphabetical order
- ✓ 5910B Compatible Commands

Remote Command Reference Summary

This section contains all of the commands for the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers, listed in alphabetical order. Table 4.1 contains a list and a description of each IEEE 488.1 common command. Table 4.2 contains the instrument specific commands. Unless otherwise noted, each of the instrument specific commands has a corresponding query without a parameter. See Figure 3.3 for the command path tree structure.

Table 4.1 – Remote Command Summary of IEEE 488.1 Common Commands

COMMAND SYNTAX	FUNCTION
*CLS	Resets the Standard Event Register, Status Byte and Error Queue to zero.
*ESE <integer>	Sets the Standard Event Status Enable Register.
*ESE?	Returns the value of the Standard Event Status Enable Register.
*ESR?	Returns the value of the Standard Event Status Register.
*IDN?	Returns the Device Identification string.
*OPC	Generates the Operation Complete message in the Standard Event Status Register.
*OPC?	Places an ASCII character 1 into the Output Queue.
*PSC	Used to avoid any undesirable service requests.
*PSC?	Queries the Power-On-Status-Clear Flag.
*RCL <integer>	Used to recall a stored setup configuration.
*RST	Forces a device reset.
*SAV <integer>	Saves the current setup configuration.
*SRE <integer>	Sets the Service Request Enable Register bits to allow generation of user-selectable service requests.
*SRE?	Returns the current contents of the Service Request Enable Register.
*STB?	Returns the current contents of the Status Byte Register.
*TST?	Initiates an internal self-test and returns a response when complete.
*WAI	Prevents executing any further commands until the No-Operation-Pending flag is true.

Table 4.2 – Instrument Specific Command Summary Reference List

NAME	FUNCTION
:ANALoginput ON OFF 1 0	Determines whether temperature modulation is enabled via the analog in BNC.
:CABLER <ohms>	Output Cable Resistance setting
COND?	Queries device conditions.
CONST:ICI <slope>,<offset>	Gain and Offset for temperature to current transducer.
CONST:ICI:SLOPe < μ A/K>	Slope only control
CONST:ICI:OFFSet < μ A>	Offset only control
CONST:ICV <slope>,<offset>	Gain and Offset for temperature to voltage transducer.
CONST:ICV:SLOPe <mV/K>	Slope only control
CONST:ICV:OFFSet <mV>	Offset only control
CONST:RTD <A>,,<C>,<R ₀ >	Callendar-Van Dusen constants for RTD measurement.
CONST:RTD:[A B C R0] <value>	Individual Callendar-Van Dusen coefficients.
CONST:THERMistor <C1>,<C2>,<C3>	Steinhart-Hart thermistor coefficients
CONST:THERMistor:[C1 C2 C3]	Individual Steinhart-Hart coefficients.
DISPlay ON OFF 1 0	Blanks the front panel display
DISPlay:BRIgHTness <1-10>	Controls VFD Brightness
ENABle:COND	Programs conditions to set in the status byte.
ENABle:EVEnt	Programs events to set in the status byte.
ENABle:OUTOFF	Programs which events cause the output to shutoff.
ERRors?	Queries the errors in the error queue.
EVEnt?	Queries device events.
FAN ON OFF 1 0	Enables or disables an external fan.
FAN:VOLTage <volts>	External fan voltage.
LIMit:ITE:High <amps>	Upper TEC current limit
LIMit:ITE:LOw <amps>	Lower TEC current limit
LIMit:SENsor:High <resistance μ A mV>	Upper sensor protection (sensor mode)
LIMit:SENsor:LOw <resistance μ A mV>	Lower sensor protection (sensor mode)
LIMit:Temp:HIgh <degrees>	Upper temperature protection (temp mode)
LIMit:Temp:LOw <degrees>	Lower temperature protection (temp mode)
LIMit:TOLerance <value>	Setpoint tolerance window
MEASure:ITE?	Measured TEC current
MEASure:SENsor?	Measured sensor value R, A, mV
MEASure:Temp?	Measured temperature.
MEASure:VTE?	Measured TEC voltage
MODE T SENSOR ITE	Output control mode
:OUTPut ON OFF 1 0	Enables the TEC Output

NAME	FUNCTION
PID <P>,<I>,<D>	Temperature Control Loop PID constants
PID:ATUNE RUN STOP	Auto PID Tuning returns (IDLE RUNNING PASS FAIL)
PID:PRESET <Name>	Stored PID Presets
RADix BINary DECimal HEXadecimal OCTal	Returned integer format
SENsor ICI ICV THERM10UA THERM100UA THERMAUTO THERMLINEAR RTD1MA RTD2_5MA	Temperature sensor selection
SET:ITE <amps>	TEC Current Setpoint (ITE mode)
SET:SENsor <value>	Sensor Control Setpoint (sensor mode)
SET:Temp <degrees>	Temperature Control Setpoint (temp mode)
STATus?	Value of the device status register.
SYNTAX 1 0	5910B compatible commands for 5910C

LDT-5910B Compatibility for LDT-5910C

To enable compatibility from the 5910B send SYNTAX 0.

The following commands are provided for compatibility with software written for the 5910B:

:COND?	INC	R?
:CONST	ITE?	RADix
:CONST?	:LiMit:ITE	RADix?
:DEC	:LiMit:ITE?	SET:R?
:ENABle:COND	:LiMit:THI	SET:T?
:ENABle:COND?	:LiMit:THI?	SENsor?
:ENABle:EVEnt	:LiMit:TLO	STEP
:ENABle:EVEnt?	:LiMit:TLO?	STEP?
:ENABle:OUTOFF	MODE?	:T
:ENABle:OUTOFF?	MODE:R	:T?
:ERRors?	MODE:T	:TOlerance
:EVEnt?	OUTput	:TOlerance?
GAIN	OUTput?	
GAIN?	R	

The following 5910B commands are not compatible:

*IST	:DiSplay:AUTO	:LOCK:ADJ?
*PRE	:DiSplay:AUTO?	MESSage
*PRE?	:DiSplay:R	MESSage?
*PUD	:DiSplay:R?	:SECURE
*PUD?	:DiSplay:SET	:SYNTAX
:CAL:ITE	:DiSplay:SET?	:SYNTAX?
:CAL:ITE?	:DiSplay:T	:TERM
:CAL:SENsor	:DiSplay:T?	:TERM?
:CAL:SENsor?	ITE	:TIME?
:DELAY	:LOCK:ADJ	:TIMER?

Command Reference

The following pages contain a reference for common commands of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers.

*CLS

Clear Status

Description	Clears all status event registers and the error queue
Notes	Useful to clear registers before enabling service requests (SRQ)
Examples	*CLS

*ESE <integer>

Standard Event Status Enable

Description	Sets the bits in the standard event status enable register.
Parameters	The value must be between 0 and 255.
Notes	<p>The integer sent as a parameter is expressed in binary form when an event occurs in the standard event status register that matches the corresponding bit in the standard event status enable register; bit 5 will be enabled in the status byte register</p> <p>See *ESR? for a description of each bit in the status register along with a diagram of the reporting structure.</p>
Examples	"*ESE 40" Sets the standard event status enable register to enable bit 5 of the status byte register if a device-dependent error or a command error occurs ($40 = 2^3 + 2^5$)

*ESE?

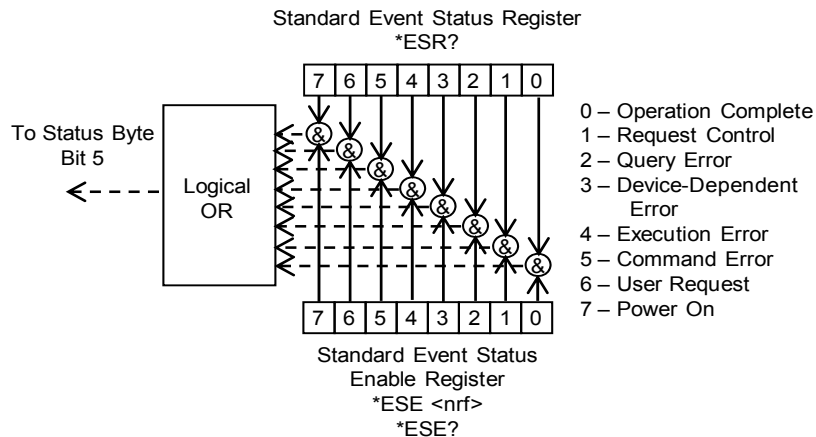
Event Status Enable Query

Description	Determine the contents of the standard event status enable register
Parameters	None
Notes	<p>The response is a value between 0 and 255, representing the bits of the standard event status enable register when expressed in base 2 binary format</p> <p>See *ESR? for a description of each bit in the status register along with a diagram of the reporting structure</p>
Examples	"*ESE?" A response of 68 means the user request and query error bits have been enabled in the standard event status enable register ($68 = 2^2 + 2^6$)

*ESR?

Standard Event Status Register Query

Description	Determine the contents of the standard event status register
Parameters	None
Notes	Reading this register clears the contents. The response is a value between 0 and 255, representing the bits of the standard event status register when expressed in base 2 binary format. The event bit is set when a specific event occurs:



Bit 0	Operation Complete is set when all pending device operations have been finished after *OPC common command has been executed
1	Unused and always reports 0
2	Query Error means that data in the output has been lost or that none was available
3	Device-Specific Error is an error has occurred that is neither a command query or execution error
4	Execution Error means a parameter was evaluated to be outside the legal input range or capability
5	Command Error means a command could not be interpreted by the parser
6	Unused and always reports "0"
Bit 7	Power On indicates that an off-to-on transition has occurred in the power supply *CLS will clear this register

Examples “*ESR?” A response of 32 means a command error has occurred

*IDN?

Instrument Identification

Description	Requests the instrument to identify itself
Parameters	None
Notes	Returns a string of instrument identification information. The string contains a comma separated list of manufacturer, model number, serial number, and firmware revision.
Examples	“*IDN?” Responds with “ILX Lightwave,LDT-5910C,59101111,1.00-1.00”

***OPC**

Operation Complete

Description	Sets the operation complete bit (bit 0) in the standard event status register when all pending overlapped commands have been completed
Parameters	None
Notes	This command does not hold off subsequent operations. You can determine when the overlapped commands have completed either by polling the standard event status register (*ESR?) or by setting up the status system such that a serve request is asserted when bit 0 is set in the standard event status register.
Examples	OUTPUT ON;*OPC Will set bit 0 in the standard event status register when the output is on

***OPC?**

Operation Complete Query

Description	Places an ASCII character 1 into the instrument's output queue when all pending operations have been finished
Parameters	None
Notes	This command is a sequential command that holds off all subsequent commands until the "1" is returned. Make sure you have set the timeouts appropriately for using this command when you expect long delays.
Examples	*OPC? A response of "1" means that all overlapped commands are complete

***PSC <number>**

Power-on Status Clear

Description	Sets automatic power-on clearing of the enable registers				
Parameters	A number that rounds to the integer zero disables the power-on clearing of enable register while any other number enables the power-on clearing of enable registers.				
Notes	<p>Registers affected:</p> <table><tr><td>Condition Status Enable</td><td>Service Request Enable</td></tr><tr><td>Event Status Enable</td><td>Standard Event Status Enable</td></tr></table> <p>Factory default condition: Disabled</p> <p>In the disabled state, the values of the enable registers are saved through power OFF/ON. The power-on status clear flag (see *PSC?) is set to false, disallowing service request interrupts after power-on.</p> <p>In the enabled state, the enable registers are cleared during power-on. The power-on status clear flag (see *PSC?) is set to true, allowing service request interrupts after power-on.</p>	Condition Status Enable	Service Request Enable	Event Status Enable	Standard Event Status Enable
Condition Status Enable	Service Request Enable				
Event Status Enable	Standard Event Status Enable				
Examples	<p>*PSC 0 Disable automatic power-on clearing of the enable registers</p> <p>*PSC 1 Enable automatic power-on clearing of the enable registers</p>				

***PSC?**

Power-on Status Clear Query

Description	Requests the status of the power-on status clear flag		
Parameters	None		
Notes	Response:	0 – The enable registers are saved through power off/on.	
		1 – The enable registers are cleared during power on.	
	Registers affected:		
		Condition Status Enable	Service Request Enable
		Event Status Enable	Standard Event Status Enable
	See Chapter 3 for more information on register structure		
Examples	*PSC?	Requests state of power-on status clear flag	

***RCL <bin>**

Recall

Description	Recalls a stored setup configuration from memory
Parameters	A value from 0 – 10
Notes	Bin 0 is the factory-set default configuration
	The *SAV function is used to save configurations for convenient recall
	The current setup is automatically stored and recalled at the next power-on
Examples	“*RCL 0” –response: instrument is reconfigured to factory-default settings

***RST**

Reset

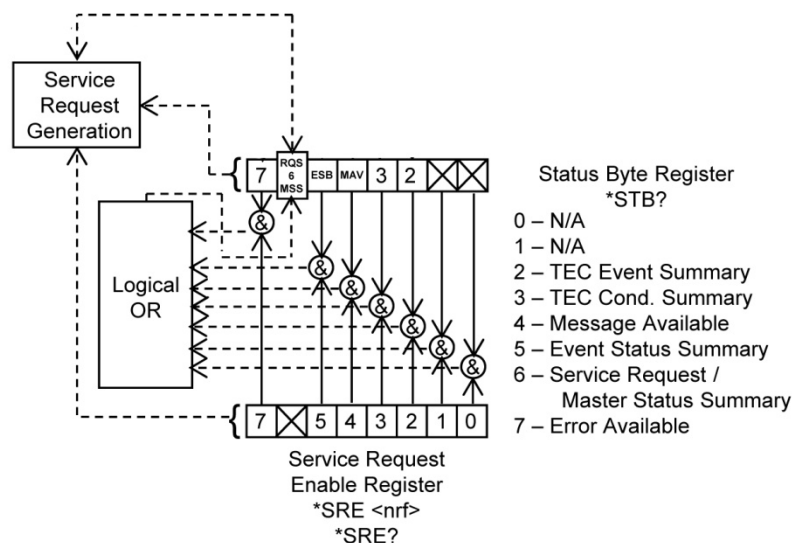
Description	Performs a device reset
Parameters	None
Notes	<ol style="list-style-type: none">1. Clears *OPC or *OPC? device requirements2. Stops operation of overlapped commands3. Sets all device specific function to a known state (*RST Value)
	The reset command does NOT affect the following: <ol style="list-style-type: none">1. Output Queue2. Enable Registers3. Event Registers4. *PSC state5. Memory contents associated with *SAV

***SAV <bin>** Save

Description	Saves the current instrument configuration to non-volatile memory
Parameters	A value from 1 – 10
Notes	<p>The *SAV operation saves the contents of everything affected by the *RST command. It is not necessary to save the current setup for next power-on. The current setup is automatically stored and recall at next power-on.</p> <p>Use *RCL <bin> to restore the saved configuration</p>
Examples	“*SAV 3” The current instrument configuration is stored in memory bin 3

***SRE <integer>** Service Request Enable Command

Description	Sets the service request enable register bits
Parameters	A value in the range of 0 to 255
Notes	<p>The integer sent as a parameter when expressed in binary format, each bit represents a bit in the service request enable register. A bit value of one indicates an enabled condition. A bit value of zero indicates a disabled condition. Bit 6 will be ignored.</p> <p>Setting the service request enable register allows the programmer to select which summary messages in the status byte register may cause service requests. Each bit in the service request enable register corresponds to a bit in the status byte register.</p> <p>A service request is generated when a bit in either the service request enable register or the status byte register transitions from zero to one and the corresponding bit in the other register is either set to one or transitions from zero to one at the same time.</p> <p>Chapter 3 has detailed information on status reporting.</p>



Examples	“*SRE 16” Enables the service request enable register to generate a service request when a query generating message is available to read from the output queue.
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*SRE?

Service Request Enable Query

Description Returns the enabled bits in the service request enable register

Parameters None

Notes The response is a value between 0 and 255, representing the bits of the standard event status enable register when expressed in base 2 binary format

Examples “*SRE?” A response of 16 signifies that the message available summary bit is enabled

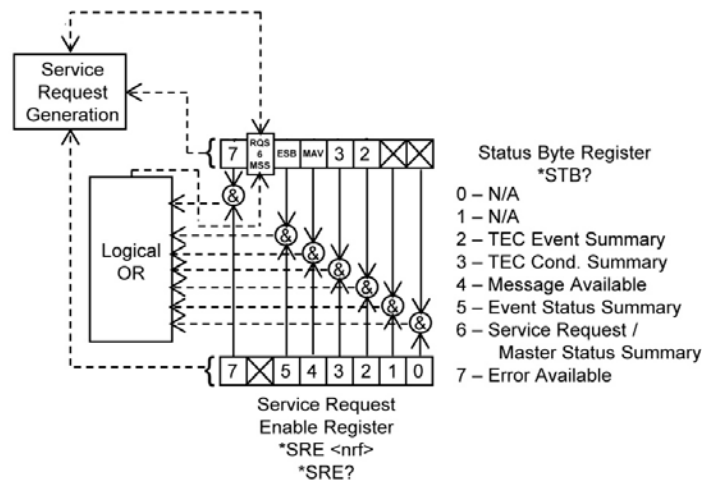
*STB?

Status Byte Query

Description Returns the value of the status byte register

Parameters None

Notes The response is the sum of the enabled bits and must be a value between 0 and 255



Examples “*STB?” A response of 200 specifies that the TEC condition summary, master status summary and error available bits are enabled

*TST?

Self Test

Description Performs an internal self-test and then reports results

Parameters None

Notes Response 0 = test completed with no errors
Response 1 = test completed with errors

This is a synchronous command and will block other commands from execution until it has completed

Examples “*TST?” A response of 0 means tests completed without errors

***WAI**

Wait to Continue

Description	Prevents the instrument from executing any further commands until all pending operations are complete
Parameters	None
Notes	<p>This command can be used to make the instrument wait until an operation is complete before continuing</p> <p>Care should be taken to set the time-out appropriately for use with the *WAI command. After this command is sent, the instrument may block subsequent commands waiting for the input queue to empty.</p>
Examples	<p>“:OUTPUT ON;*WAI::MEAS:T?” The temperature measurement will occur after the output is on</p>

The following pages contain a reference for device-dependent commands of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers.

:ANALoginput ON|OFF|1|0
:ANALoginput?

Description Enables the analog input rear panel BNC to be used for temperature modulation.

Parameters ON/1 – Temperature Modulation ON
OFF/0 – Temperature Modulation OFF

Reset Value OFF

:CABLER <ohms>
:CABLER?

Description Output cable resistance used to improve the accuracy of the **MEASure:VTE?** command

Parameters ohms – Cable resistance

Notes Voltage measurement subtracts this resistance multiplied by output current to get actual voltage

Reset Value 0.02

:CONST:ICI <slope>,<offset>
:CONST:ICI?

Description Slope and offset compensation for a temperature to current transducer.

Parameters slope – 0 to 9.999 representing the $\mu\text{A/K}$ response of the temperature to current transducer.
offset – -9.999 to 9.999 representing the sensor offset in μA

Reset Value 1,0

:CONST:ICI:SLOPe < $\mu\text{A/K}$ >
:CONST:ICI:SLOPe?

Description Slope compensation for a temperature to current transducer.

Parameter 0 to 9.999 representing the $\mu\text{A/K}$ response of the temperature to current transducer.

Reset Value 1

:CONST:ICI:OFFSet < μA >
:CONST:ICI?

Description Offset compensation for a temperature to current transducer.

Parameters -9.999 to 9.999 representing the sensor offset in μA

Reset Value 0

:CONST:ICV <slope>,<offset>
:CONST:ICV?

Description Slope and offset compensation for a temperature to voltage transducer.

Parameters slope – 0 to 99.99 representing the mV/K response of the temperature to current transducer.
offset – -99.99 to 99.99 representing the sensor offset in mV

Reset Value 10, 0

CONST:ICV:SLOPe <mV/K>
:CONST:ICV:SLOPe?

Description Slope compensation for a temperature to voltage transducer.

Parameter 0 to 99.99 representing the mV/K response of the temperature to current transducer.

Reset Value 10

:CONST:ICV:OFFSet <mV>
:CONST:ICV:OFFSet?

Description Offset compensation for a temperature to voltage transducer.

Parameter -99.99 to 99.99 representing the sensor offset in mV

Reset Value 0

:CONST:RTD <A>,,<C>,<R0>
:CONST:RTD?

Description Callendar-Van Dusen coefficients for RTD temperature transducer.

Parameters

A	-9.999 to 9.999 representing the first coefficient of the Callendar-Van Dusen equation multiplied by $10^{-3} \text{ }^{\circ}\text{C}^{-1}$
B	-9.999 to 9.999 representing the second coefficient of the Callendar-Van Dusen equation multiplied by $10^{-7} \text{ }^{\circ}\text{C}^{-2}$
C	-9.999 to 9.999 representing the third coefficient of the Callendar-Van Dusen equation multiplied by $10^{-12} \text{ }^{\circ}\text{C}^{-3}$
R0	The resistance of the transducer at 0 °C, adjustable from 0 to 9999.9 Ohm

Notes The Callendar-Van Dusen equation:
 $R_T = R_0[1 + AT + BT^2 + CT^3(T - 100)]$ ($T < 0 \text{ }^{\circ}\text{C}$)
 $R_T = R_0[1 + AT + BT^2]$ ($T \geq 0 \text{ }^{\circ}\text{C}$)
Where R_T is the resistance at temperature T .

Reset Value 3.908,-5.775,-4.183,100

Examples CONST:RTD 3.4, 7.0, 5.0, 100.1 action: sets the RTD coefficients as follows: A=3.4, B=7.0, C=5.0, Ro = 100.1
CONST:RTD? response: 3.4,7.0,5.0,100.1: The RTD coefficients are A = 3.4, B = 7.0, C = 5.0 and R0 = 100.1

:CONST:THERMistor <C1>,<C2>,<C3>
:CONST:THERMistor?

Description	Steinhart-Hart parameters for a thermistor temperature transducer.		
Parameters	C1	-9.9999 to 9.9999 representing the first parameter of the Steinhart-Hart equation multiplied by 10 ⁻³	
	C2	-9.9999 to 9.9999 representing the second parameter of the Steinhart-Hart equation multiplied by 10 ⁻⁴	
	C3	-9.9999 to 9.9999 representing the third parameter of the Steinhart-Hart equation multiplied by 10 ⁻⁷	
Notes	The Callendar-Van Dusen equation: $\frac{1}{T} = C1 - C2 \cdot \ln(R) + C3 \cdot \ln^3(R)$ Where <i>R</i> is the resistance at temperature <i>T</i> .		
Reset Value	1.125, 2.347, 0.855		
Examples	CONST:THERMistor 1.25, 2.36, 0.76 action: Sets the Steinhart-Hart coefficients to C1 =1 .25, C2 = 2.36, and C3 = 0.76.		
	CONST:THERMistor? Response: 1.25, 2.36, 0.76: C1 = 1.25, C2 = 2.36, and C3 = 0.76.		

:DISPLay ON|OFF|1|0

Description	Display on/off
Parameters	0/OFF = Display off 1/ON = Display on
Notes	LED is not turned off when display is off
Examples	DISPLAY? - Response "0" means the display is currently shut off Disp? - Response "1" means the display is in normal state.

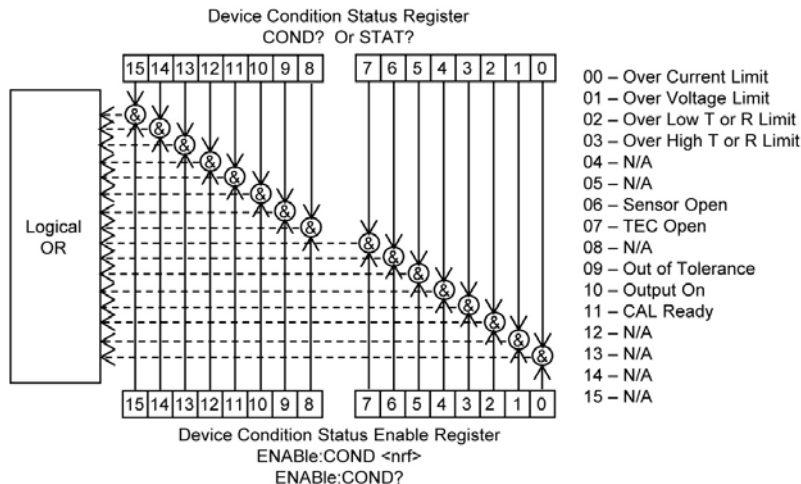
:DISPLay:BRIGHTness <1-10>

Description	Adjusts the brightness on the VFD Display
Parameter	Integer representing the brightness; the higher the number the brighter the display.
Notes	LED brightness is not adjustable.
Examples	:DISPLay:BRIGHTness 5 – Set to medium display brightness.

:ENABLE:COND <integer> :ENABLE:COND?

Description Enables bits in the device condition status enable register.

Parameters 0 to 65535



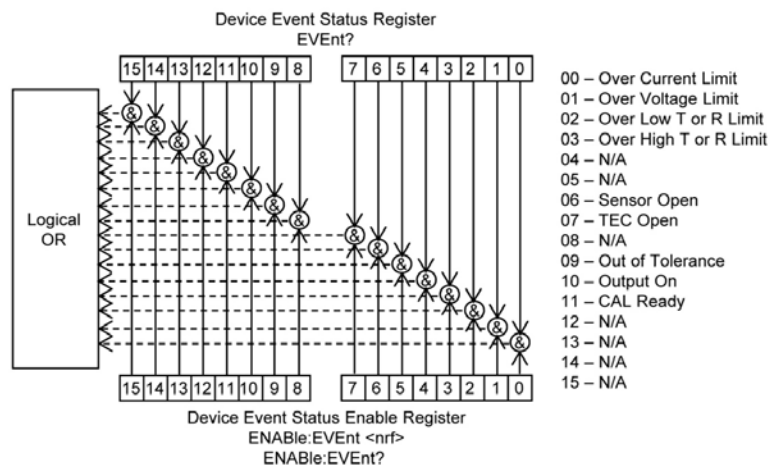
Notes Enabled/disabled conditions can be set by ENABLE:COND?. Changing condition status may be monitored by COND?. See Chapter 3 for more information about register structure.

Examples ENAB:COND? - Response 1 means that over current limit will be reported in status byte bit 3.
Enable:COND? - Response #H1 is the same as 1, except using hexadecimal numbering. See RADix.

:ENABLE:EVEnt <integer> :ENABLE:EVEnt?

Description Enables bits in the device event status enable register.

Parameters 0 to 65535



Notes Enabled/disabled events can be read by ENABLE:EVEnt?. Event status may be monitored by EVEnt?.

Bit 2 of the status byte register is set if any device enabled events are true, for generation of service requests.

See Chapter 3 for more information about register structure.

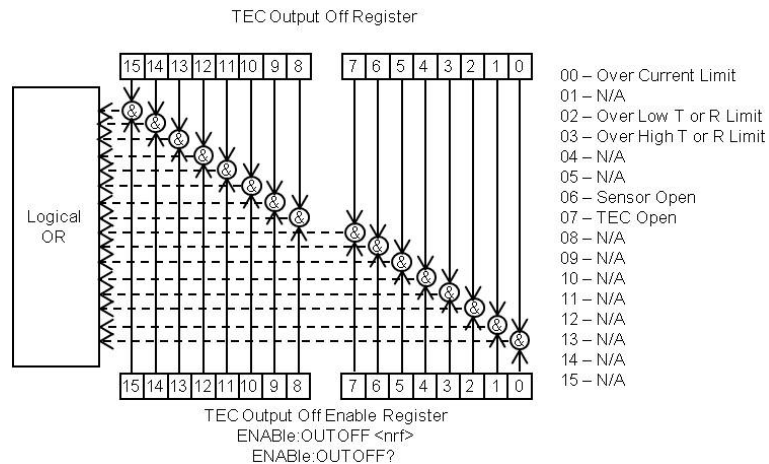
Enable registers normally retain their values through power OFF/ON, unless the power-on status clear flag is set true. See *PSC.

Examples ENAB:EVE 64 - Enables Sensor Open event to be summarized in the status byte bit 2.
Enable:event #H40 - Same as ENAB:EVE 64, except using hexadecimal numbering. See RADix.

ENABLE:OUTOFF <integer> ENABLE:OUTOFF?

Description Enables bits in the device output off enable register.

Parameters 0 to 65535



Notes Enable registers normally retain their values through power OFF/ON, unless the power-on status clear flag is set true. See *PSC.

Examples ENAB:OUTOFF 1 - Enables the over current limit condition to turn off output.

:ERRors?

Description Requests a list of errors which have occurred since the last ERR? request.

Parameters None

Response ASCII character string: list of error numbers, separated by commas.

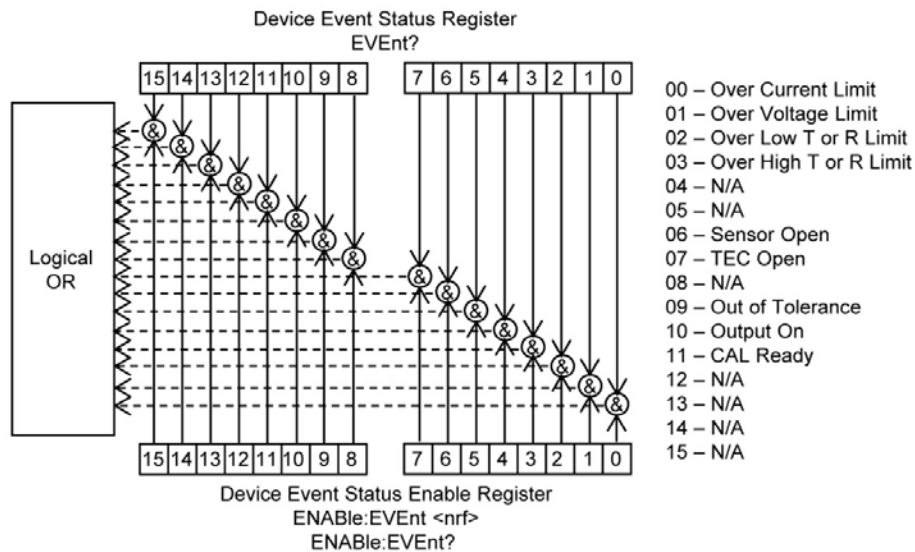
Notes 0 = no errors reported.
See chapter 5 for a list of error numbers.

Examples ERR?- Response 0 means no errors to report.
Errors? - Response 501 means over temperature.

:EVENT?

Description Requests the value in the device event status register.

Response A value between 0 and 65535



Notes Enabled/disabled events can be set by ENABLE:EVEnt.
Status bits are set by events, and cleared when read or cleared by command. See *CLS and EVEnt? commands.

See Chapter 3 for more information about register structure.

Examples EVE? - Response 2048 means that cal ready events occurred since the last EVE? inquiry.
Event? - Response #H800 is the same as 2048, except using hexadecimal numbering. See RADix.

:FAN ON|OFF|0|1 :FAN?

Description External fan on/off control

Parameters ON/1 = Fan on
OFF/0 = Fan off

Notes Use the **FAN:VOLTage** command to configure the fan voltage.

Reset Value 0

Examples FAN 0 – turn fan off

:FAN:VOLTage <volts> :FAN:VOLTage?

Description External fan voltage

Parameters Volts – External fan voltage

Notes Use the **:FAN** command to turn the external fan on or off.

Reset Value 12

Examples FAN:VOLT 11; FAN ON; -- Apply 11 Volts to the fan.

:LIMit:ITE:High <amps>**:LIMit:ITE:High?**

Description Upper TEC current limit

Parameters Amps – Output current is clipped below this value in all control modes.

Notes Use in conjunction with **:LIMit:ITE:Low** to control the limit. An error will be generated for a setpoint lower than the LOW limit.

Reset Value 2.5 A

Examples LIM:ITE:HI? response: 0.9, means the upper current limit is 0.9 A.

:LIMit:ITE:Low <amps>**:LIMit:ITE:Low?**

Description Sets the more negative peak limit of TEC current.

Parameters Amps – Output current is clipped above this value in all control modes.

Notes Use in conjunction with **:LIMit:ITE:High** to control the limit. An error will be generated for a setpoint lower than the HIGH limit.

Reset Value -2.5 A

Examples LIM:ITE:LO? response: -4.0, means the lower current limit is -4.0 A.

:LIMit:SENsor:High <resistance|uA|V>**:LIMit:SENsor:High?**

Description Sets the more positive sensor measurement.

Parameters Dependant on the sensor selected, when using a thermistor or an RTD sets maximum resistance. In ICI and ICV maximum current and voltage respectively.

Notes Only used in sensor mode.

Reset Value 40000

Examples Sensor THERM100UA; LIM:SEN:HI 4501.00 action: Sets the sensor upper limit to a maximum of 4501 Ohm.

:LIMit:SENsor:Low <resistance|uA|V>**:LIMit:SENsor:Low?**

Description Sets the more negative sensor measurement.

Parameters Dependant on the sensor selected, when using a thermistor or an RTD sets minimum resistance. In ICI and ICV minimum current and voltage respectively.

Notes Only used in sensor mode.

Reset Value 0

Examples Sensor THERM100UA; LIM:SEN:LO 450.00 action: Sets the sensor lower limit to a minimum of 450 Ohm.

:LiMit:Temp:Hgh <degrees>**:LiMit:Temp:Hgh?**

Description Sets the more positivie temperature at which the temperature controller will turn off.

Parameter Degrees – maximum temperature at which the controller will shut off.

Notes Only used in T mode.

Reset Value 50

Examples LIM:T:HI 105.0 action: sets the high temperature limit to 105.0 °C.

:LiMit:Temp:LOw <degrees>**:LiMit:Temp:LOw?**

Description Sets the more negative temperature at which the temperature controller will turn off.

Parameters Degrees – minimum temperature at which the controller will shut off.

Notes Only used in T mode.

Reset Value 0

Examples LIM:T:LO -20.0 action: sets the lower temperature limit to -20.0 °C.

:LiMit:TOLerance <value>

Description Sets the settling tolerance for determining when *OPC is complete or an :EVENT? is set

Parameter This value is the settling value dependant on mode. Takes the same units as the :SET: commands.

Notes This has a maximum timeout of 30 seconds when used with *OPC commands. This value is only applicable in T mode.

Reset Value .2

Examples LIMit:TOL? response: 0.3 means a tolerance window of +0.3 °C

:MEASure:ITE?

Description Measured TEC current

Response Amps - TEC current

Notes Positive current indicates the TEC is cooling. Negative current indicates the TEC is heating

Examples MEAS:ITE? response: 2.2 means the controller output current is set to 2.2 A.

:MEASure:SENSor?

Description Measures the sensor value.

Response	Ohms - Resistance when using a thermistor or RTD. μ A and V when using ICI and ICV sensors respectively.
Notes	The response is the measured sensor, regardless of control mode, and the units are dependent upon which sensor is selected. For thermistor or RTD, the value will be in ohms, ICI in MicroAmps, ICV in Volts.
Examples	MEAS:SEN? response: 0.0001323 means the measured sensor value is 132.3 μ A, (if instrument sensor is set for ICI).

:MEASure:Temp?

Description	Measured sensor temperature.
Response	Degrees - Temperature in °C.
Notes	Relies on having the proper sensor selected and the appropriate constants.
Examples	MEAS:T? response: 45.6 means the measured temperature is 45.6 °C.

:MEASure:VTE?

Description	Measured TEC voltage
Response	Volts - TEC Voltage in volts.
Notes	Use the :CABLER command to configure the cable resistance for the most accurate measurements.
Examples	MEAS:VTE? response: 4.2 means the measured output voltage is 4.2 V.

:MODE T|SENSOR|ITE

:MODE?

Description	Configures the control mode of operation.
Parameters	T – Temperature control mode. Controls to a temperature setpoint using the selected sensor. SENSOR – Sensor value control mode. Controls to a Resistance, Current or Voltage depending on the sensor selected. ITE – Continuous current mode, or open loop. Directly controls current to the TEC.
Notes	The :SET:ITE , :SET:SEnSor and :SET:Temp are used to control the setpoint. :LIMit:SEnSor and :LIMit:Temp are active only in their respective modes. :LIMit:ITE is active in all modes of operation.
Reset Value	T
Examples	MODE?; response: T, means that the controller is in constant temperature control mode.

:OUTPut ON|OFF|1|0

:OUTPut?

Description	Controls whether the output is enabled or not
Parameters	ON/1: Turns the output on OFF/0: Turns the output off

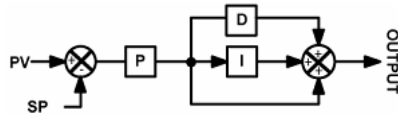
Notes	The output on bit 10 in the event or condition status register can be used to determine the actual point that the output is turned on, or if it has automatically shut off due to an error condition. Additionally, *OPC? Or *WAI may be used to determine the time when the output reaches setpoint.
Reset Value	OFF
Examples	“OUTP?” A response of 0 means that the TEC output is off “OUTP ON” Enables pulse output

:PID <P>,<I>,<D>

:PID?

Description Temperature and sensor mode control loop constants.

Parameters P – Proportional or Gain Term. Determines how fast the control responds to changes in temperature.
I – Integral Term or Resets/second. Integrates the error to correct for disturbances. Necessary for TEC controllers.
D – Derivative Term or Lead Compensation. This term is forward looking and corrects the controller that is moving to quickly toward the setpoint.



Notes The diagram for the PID controller is shown above. The formula in classical notation is:

$$Current = P \left[e(t) + I \int e(t) dt + D \frac{de(t)}{dt} \right] \text{ where } e(t) = Setpoint - Temperature$$

Reset Value 20, 0.5, 0

Examples PID 24, 5.6, 8.0 action: sets P=24.00, I=5.600, and D=8.000
 PID 25 action: sets P=25.00. I and D are unchanged.

:PID:ATUNE RUN|STOP

:PID:ATUNE?

Description Controls the PID auto-tune functionality. The auto-tune only works in T and R modes.

Parameters RUN – Starts the auto PID tuning algorithm.
 STOP – Halts the auto tuning algorithm.

Responses IDLE – The PID autotuning algorithm has not been performed.
 RUNNING – The auto-tune algorithm is performing an analysis.
 PASS – The auto-tune algorithm has completed and values have been saved to the system constants.
 FAIL – The auto-tune algorithm could not complete. System PID values have not been updated.

Reset Value IDLE

Examples PID:ATUNE:RUN – Action: Start autotuning

:PID:PRESET <name>

:PID:PRESET?

Description Restores preset PID constants for 5910B compatibility and select laser diode mounts.

Parameters name – DEFAULT, GAIN1, GAIN3, GAIN10, GAIN30, GAIN100, GAIN300, LDM4405, LDM4407, LDM4409, LDM4412, LDM4980, and LDM4990.

Response Returns a list of comma separated strings that are all of the valid preset commands.

Notes The 5910B compatible gains are called with GAIN# where # is the gain number for the 5910B. For preset mounts the syntax is the model name of the mount without dashes, i.e. LDM4405 is the preset constraints for an LDM-4405. The response includes each preset value in quotes. To set a preset quotes are not used.

Reset Value DEFAULT

Examples PID:PRESET LDM4405; -- Action: will use the default PID values for the LDM4405 mount.

:RADIX BINary|DECimal|HEXadecimal|OCTal :RADIX?

Description Determines the response data format for the status, event and enable registers.

Parameters BINary – Returns the value in binary, base 2, format prefixed with #B
DECimal – Returns the value in decimal format.
HEXadecimal – Returns the value in hexadecimal, base 16, format prefixed with #H
OCTal – Returns the value in octal, base 8, format prefixed with #O

Notes This does not affect the sending of data. Any format can be used to send data as long as the proper prefix is used.

Reset Value DECIMAL

Examples "RAD dec" action: the decimal radix is selected.

:SENSor <name>**:SENSor?**

Description Sensor selection for temperature conversion and for use in sensor mode.

Parameters ICI – Temperature to current transducer, i.e. AD590
ICV – Temperature to voltage transducer, i.e. LM335
THERM10UA – Thermistor with a 10 uA current source. Good for resistance > 450 kΩ.
THERM100UA – Thermistor with a 100 uA current source. Good for resistance < 45 kΩ
THERMAUTO – Thermistor with auto switching between 10 uA and 100 uA improves the measurement range
THERMLINEAR – Places a 10 kΩ resistor in parallel with the thermistor to improve the accuracy and range of 10 kΩ thermistor measurements.
RTD1MA – Resistive temperature device, i.e. PT1000, with a 1 mA current source. Good for resistance > 200 Ω
TRD2_5MA – Resistive temperature device, i.e. PT100, with a 2.5 mA current source. Good for resistance < 200 Ω.

Notes

Reset Value THERM100UA

Examples SEN THERM100UA action: sets the sensor to thermistor and the sense current to 100 µA.

:SET:ITE <amps>**:SET:ITE?**

Description Constant current setpoint for use in ITE mode.

Parameter Amps – Constant current setpoint in amps between -4 and 4. This will be clipped by the LIMIT:ITE values.

Notes

Examples SET:ITE 2.5 action: sets the setpoint for ITE mode to 2.5 A.

:SET:SENSor <value>**:SET:SENSor?**

Description Configures the control setpoint for use in sensor mode.

Parameter Value – sensor dependant value for the control point. For thermistors and RTDs it is in ohms. For ICI and ICV it is in microamps and volts respectively.

Notes Set this value after setting the SENSor as toggling between sensors will affect the range.

Reset Value 10000

Examples SET:SENSor 0.002932 action: sets the setpoint for the ICV sensor to 2.93 mV.

:SET:Temp <degrees>**:SET:Temp?**

Description Configures the temperature setpoint for use in temp mode

Parameter Degrees – the setpoint in °C for which the temperature will control to in temp mode.

Notes

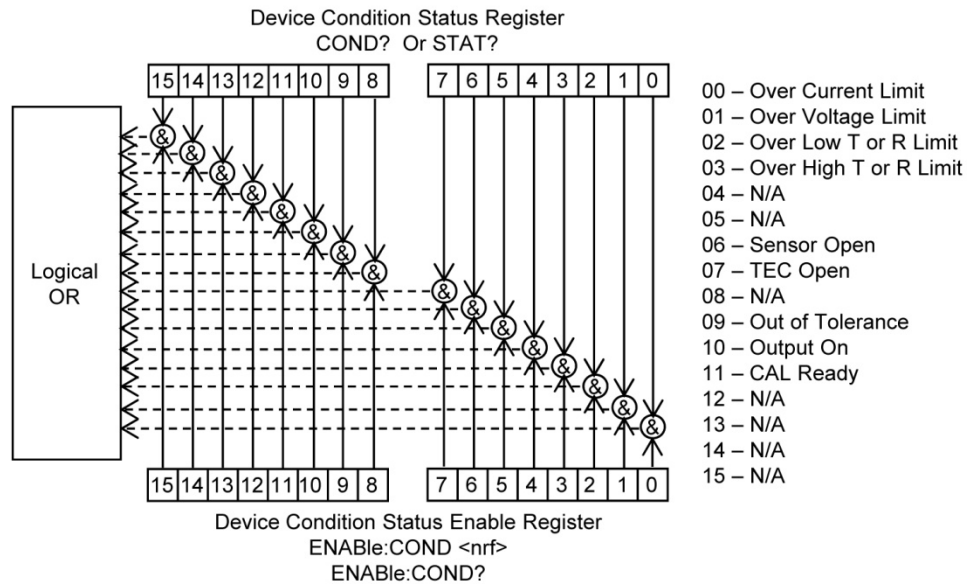
Reset Value 25

Examples SET:T 75.43 action: sets the temperature setpoint to 75.43 °C.

:COND? :STATus?

Description Requests the contents of the device condition status register.

Response A value between 0 and 65535



Notes The conditions reported to the status byte are set through the ENABLE:COND command.

The condition status may be constantly changing, while the event status is only cleared when it is cleared or read. See *CLS and EEnt? commands.

See Chapter 3 for more information about register structure.

Examples COND? - Response 1 means there is an over current limit condition.
STAT? - Response 0x600 means output is on and it is out of tolerance.

:SYNTAX 1|0 :SYNTAX?

Description Sets the unit for compatibility with LDT-5910B

Parameters 0 – LDT-5910B compatibility for LDT-5910C
1 – LDT-5910C AND LDT-5940C default operation

Notes This causes the **COND?** and **EVENT?** registers to match the LDT-5910B model. This will hide some conditions and functionality available in the LDT-5910C. This is recalled at power up.

Reset Value Not affected by *RST

Examples Syntax 0 – Use LDT-5910B compatible commands

Chapter 5:

Calibration and Troubleshooting

This chapter is to help you resolve any problems you may experience with your LDT-5910C and LDT-5940C quickly. If you need additional help, please contact ILX Lightwave Customer Service. See page viii for contact information.

ILX Lightwave Corporation provides in-house calibration services for ILX instruments. International customers may contact our services centers for regional calibration support. Most ILX instruments, including the LDT-5910C and LDT-5940C require yearly calibration to ensure performance to published specifications. ILX factory calibrations employ NIST traceable measurement instrumentation, and our calibration engineers and technicians use automated test equipment to accurately and efficiently capture and record calibration data. An original certificate of calibration authenticity is provided with all instrument calibrations, and a detailed report showing any pre-calibration out-of-tolerance conditions is available upon request.

Calibration turn-around times are normally five business days or less. Please contact ILX Customer Support (see Comments, Suggestions, and Problems on page viii for contact information) for additional calibration information.

For further assistance with technical solutions and troubleshooting, visit www.ilxlightwave.com.

Troubleshooting Guide

This section lists some common problems and corrective actions. In the event that the corrective action does not resolve problem; please contact ILX Lightwave.

For a comprehensive list of frequently asked questions, see the ILX Lightwave website or contact ILX Lightwave Customer Service (see Comments, Suggestions, and Problems on page viii for contact information).

SYMPTOM	CORRECTIVE ACTION
The instrument does not power up	Check the power cord to make sure that it is properly connected and check the wall outlet by connecting to a known operational device.
The instrument reads "Over Temp - Disabled"	<p>The LDT-5910C or LDT-5940C has reached the user defined temperature limit. This error occurs if the LDT-5910C or LDT-5940C temperature is above the upper temperature limit or below the lower temperature limit.</p> <p>If the LDT-5910C or LDT-5940C is changing to a new setpoint which is near the temperature limit, the temperature may overshoot which will trigger the error. Verify the PID values used limit overshoot or set a higher limit.</p> <p>This may also occur if the instrument is in thermal run away where the LDT-5910C or LDT-5940C has reached the current limit but the temperature continues to rise. To correct thermal run away conditions additional heat sinking may be required.</p>
The instrument reads "Over Sens - Disabled"	<p>The LDT-5910C or LDT-5940C has reached the user defined sensor limit. This error occurs if the LDT-5910C or LDT-5940C sensor reading is above the upper sensor limit or below the lower sensor limit.</p> <p>If the LDT-5910C or LDT-5940C is changing to a new setpoint which is near the sensor limit, the sensor value may overshoot which will trigger the error. Verify the PID values used limit overshoot or set a higher limit.</p> <p>This may also occur if the instrument is in thermal run away where the LDT-5910C or LDT-5940C has reached the current limit but the sensor value continues to rise. To correct thermal run away conditions additional heat sinking may be required.</p>
The instrument reads "Error Cal Therm Auto"	The LDT-5910C and LDT-5940C cannot be calibrated in "Therm Auto" mode. To calibrate "Therm Auto" the user must calibrate the 10 μ A and 100 μ A thermistor currents.
The instrument reads "TEC Open"	Check the cable connections to the TEC and also verify the TEC module is not showing an open circuit (by measuring the resistance of the TEC), if the problem persists, contact customer support at ILX Lightwave.
The instrument reads "Sensor Open"	Check the cable connections to the sensor. Under the

	PARAM menu confirm the appropriate Sensor has been selected. If the problem persists contact customer support.
Power on, but temperature is not controlled or is unstable.	<p>If there is a SENSOR OPEN indication (Error code 505), check the sensor connections (pins 14,15). Check that the proper sensor current range is selected.</p> <p>Check that the appropriate coefficients have been set for your sensor. Refer to “Sensor Options” in Chapter 2.</p> <p>Check that the P, I and D constants are optimized for your thermal load and that the current limit value is not too low.</p> <p>If the problem persists contact customer support at ILX Lightwave.</p>
IC-Current sensor value is not changing on the LDT-5940C	Insure the 4-wire sensor voltage measurement (pins 1 and 2) are not connected to the sensor
Inaccurate sensor, TEC voltage, or TEC current measurement on the LDT-5940C	Insure the 4-wire TEC sensor connections (pins 7 and 8) are connected and the cable resistance is set to zero. For thermistor or RTD sensors insure the 4-wire sensor connections (pins 1 and 2) are connected.
The instrument reads “Internal Communication Error”	Error code 516 is the internal communication error indication that the LDT-5910C or LDT-5940C, is not functioning correctly. The instrument must be returned to ILX Lightwave if this error occurs.
No response from a remote command and the RMT indicator is off	<p>Check that a GPIB or USB A/B cable, from the system controller, is connected to the LDT-5910C and LDT-5940C. If you are using GPIB, the cable should be less than 3 meters (10 feet) long.</p> <p>Press PARAM until the GPIB address is displayed. If it is not correct, change it by pressing SET and then using the ADJUST knob until you see the correct address.</p> <p>Check that your controlling software is sending commands to the correct GPIB address or with the correct terminating character.</p> <p>Check that no two devices are set to the same GPIB address.</p> <p>Make sure that there are less than 15 devices on the bus.</p> <p>Check that total GPIB cable length is less than 20 meters (65 feet).</p> <p>Check the configuration of your GPIB controller card or COM port. Specifically note the information regarding the terminating character.</p> <p>Remove all other instruments from the GPIB bus to isolate the LDT-5910C or LDT-5940C. If this corrects the problem,</p>

	<p>re-connect one instrument at a time until the problem returns. Then check the other instrument for address conflicts and proper GPIB function.</p> <p>Read the error queue remotely (ERR?). The command syntax or command structure may be in error.</p> <p>Read the status byte (*STB?) and condition register (COND?) for possible device problems.</p>
Slow or unexpected response to remote commands	<p>Check that no two devices are set to the same GPIB address.</p> <p>Make sure that there are less than 15 devices on the bus.</p> <p>Check the configuration of your GPIB controller card or COM port. Specifically note the information regarding the terminating character.</p> <p>Check that total GPIB cable length is less than 20 meters.</p> <p>Remove all other instruments from the bus to isolate the LDT-5910C or LDT-5940C. If this corrects the problem, re-connect one instrument at a time until the problem returns. Then check the other instrument for address conflicts and proper GPIB function.</p>
The LDT-5910C or LDT-5940C is not responding to all ANSI/IEEE 488.2 commands	The LDT-5910C and LDT-5940C is not fully IEEE 488.2 compliant.
The LDT-5910C or LDT-5940C is not being recognized by USB	<p>The LDT-5910C and LDT-5940C is not USB 1.1 compliant.</p> <p>Check the USB cable connection between the LDT-5910C and LDT-5940C and the computer.</p>

Error Messages

Error messages may appear on the LDT-5910C and LDT-5940C display when error conditions occur in the instrument. In remote operation, use ERR? to read the current error list. The ERR? command returns a string containing up to 10 of the error messages that are currently in the error message queue.

Error Code Tables

The error codes are classified and placed in tables corresponding to their classification. The classifications are Command Errors, Execution Errors, Device Errors, Query Errors and Instrument Specific Errors.

Table 5.1 - Command Errors

ERROR CODE	EXPLANATION
-104	Data type error
-108	Parameter not allowed
-113	Undefined header
-115	Unexpected number of parameters
-121	Invalid character in number
-123	Exponent too large
-151	Invalid string data
-160	Block data error
-161	Invalid block data

Table 5.2 - Execution Errors

ERROR CODE	EXPLANATION
-220	Parameter error
-222	Data out of range

Table 5.3 - Device Errors

ERROR CODE	EXPLANATION
-311	Memory error

Table 5.4 - Query Errors

ERROR CODE	EXPLANATION
-410	Query interrupted
-420	Query unterminated

Table 5.5 - Instrument Specific Errors

ERROR CODE	EXPLANATION
501	Over temperature limit
502	Over sensor limit
503	Over current limit
504	TEC open
505	Sensor open
506	Autotune failure
507	Calibrate sensor in thermistor auto mode
516	Internal communication error (the instrument needs to be returned to ILX)

Calibration Overview

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers should be calibrated every 12 months or whenever performance verification indicates that calibration is necessary.

All calibrations can be done with the case closed. The instrument is calibrated by changing the internally stored digital calibration constants.

Recommended Equipment

Recommended test equipment for calibrating the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers are listed in Table 5.1. Equipment other than that shown in the table may be used if the specifications meet or exceed those listed.

Table 5.1 Recommended calibration equipment

DESCRIPTION	SPECIFICATION
DMM	8 1/2 Digit
Metal Film Resistors	36 k Ω and 360 k Ω (for Thermistor) 4.8 k Ω (for LM335) 20 k Ω (for AD590) 12 k Ω (for Linear Thermistor) 1.2 k Ω and 200 Ω (for RTD)
High Power Resistors	1 Ω 25 W (for ITE) 5 Ω , 25 W

Environmental Conditions

ILX Lightwave recommends calibration at 23 °C \pm 1.0 °C. When necessary, however, the LDT-5910C and LDT-5940C Thermoelectric Temperature Controller may be calibrated at its intended use temperature if this is within the specified operating temperature range of 10 to 40 °C.

Warm-up

The LDT-5910C and LDT-5940C should be allowed to warm-up for at least 1 hour before calibration unless otherwise specified.

Calibration Adjustments

There are seven calibrations that need to be completed for proper operation of the LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers. These calibrations pertain to sensor measurement, the ITE current measurement and the TEC voltage measurement.

If a problem arises during calibration which prevents normal completion, calibration may be aborted by pressing the display RIGHT and LEFT buttons simultaneously. This prevents alteration of stored calibration values due to the fact that new values are not saved to non-volatile memory until the last step of each calibration procedure.

Thermistor Calibration

The following procedure calibrates the 100 μ A or 10 μ A constant current sources so that thermistor resistance measurements will be accurate. This procedure does not calculate C1, C2, and C3. For information on calibrating the thermistor sensor, see Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

1. Under PARAM, set the SENSOR to 100 μ A or 10 μ A.
2. Measure and record the exact resistance of a 36 k Ω (for 100 μ A) or 360 k Ω (for 10 μ A) metal film resistor. A 4-point probe resistance measurement is recommended.
3. Connect the 36 k Ω or 360 k Ω metal film resistor to the sensor feedback pins of the 15-pin output connector of the LDT-5910C (pins 7 and 8) or the 25-pin output connector of the LDT-5940C (pins 14 and 15).
4. Enter the sensor calibration mode by pushing the parameter RECALL and mode SELECT buttons at the same time. The display will then indicate the sensor resistance in k Ω . Allow the measurement to settle for at least three seconds.
5. Press and hold in the parameter SET button and turn the ADJUST knob until the display indicates the same resistance you measured for the 36 k Ω or 360 k Ω metal film resistor.
6. Release the SET button and wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

Linearized Thermistor Mode Calibration

The following procedure calibrates the linearized thermistor mode so that linearized thermistor resistance measurements will be accurate. This procedure does not calculate C1, C2, and C3. For information on calibrating the thermistor sensor, see Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

1. Under PARAM, set the SENSOR to Linearized.
2. Measure the exact resistance of the 12 k Ω metal film resistor. A 4-point probe resistance measurement is recommended.
3. Connect the 12 k Ω resistor in parallel with a DMM to the sensor feedback pins of the 15-pin output connector of the LDT-5910C (pins 7 and 8) or the 25-pin output connector of the LDT-5940C (pins 14 and 15).
4. Enter the sensor calibration mode by pushing the parameter RECALL and mode SELECT buttons at the same time.
5. The voltage measured across the load resistor will change when the calibration mode is entered. Allow the measurement to settle for about three seconds. Use the measured voltage and the exact resistance of the 12 k Ω resistor and calculate the current using Ohm's law:

$$I = V / R$$

Where V is the measured voltage and R is the exact resistance of the external resistor.

6. Press and release the SET button. Disconnect the external, 12 k Ω resistor and measure the voltage across the Sensor+ and Sensor– pins (pins 7 and 8 for the LDT-5910C and pins 14 and 15 for the LDT-5940C). Allow the measurement to settle for about three seconds.
7. Using the voltage reading on the DMM and the current calculated in step 5, calculate the exact internal resistance, again using Ohm's law.

8. Press and hold in the parameter SET button and turn the ADJUST knob until the display indicates the same resistance calculated in step 7.
9. Reconnect the 12 k Ω resistor and measure the voltage across the resistor.
10. Disconnect the DMM.
11. Calculate the parallel resistance using the internal resistance calculated in step 7 and the measured resistance of the 12 k Ω resistor.
12. Press and hold in the parameter SET button and turn the ADJUST knob until the display indicates the same resistance as calculated in step 11.
13. Release the "SET" button and wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

IC-I (AD590 or equivalent) Sensor Calibration

The following procedure calibrates the IC-I sensor measurement so that the temperature measurement will be accurate. This procedure does not calibrate C1 and C2. For information on calibrating the IC-I sensor, see Appendix A.

1. Under PARAM, set the SENSOR to IC-I.
2. Measure the exact resistance of the 20 k Ω metal film resistor. A 4-point probe resistance measurement is recommended.
3. Connect the 20 k Ω metal film resistor and a precision voltmeter across the sensor feedback pins of the 15-pin output connector of the LDT-5910C (pins 7 and 8) or the 25-pin output connector of the LDT-5940C (pins 14 and 15).



For IC-Current sensors used with the LDT-5940C the 4-wire sensor measurements (pins 1 and 2) should not be connected. The use of the 4-wire sensor will cause inaccurate sensor measurements.

4. Enter the sensor calibration mode by pushing the parameter RECALL and mode SELECT buttons at the same time.
5. Measure the voltage at the sensor pins. Calculate the current using the resistance measured in step b.
6. Press and hold in the parameter SET button and turn the ADJUST knob until the display indicates the current calculated in step 5.
7. Release the SET button and wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

IC-V (LM335 or Equivalent) Sensor Calibration

The following procedure calibrates the IC-V sensor measurement so that the temperature measurement will be accurate. This procedure does not calibrate C1 and C2. For information on calibrating the IC-V sensor, see Appendix A.

1. Under PARAM, set the SENSOR to IC-V.
2. Connect a precision 4.8 k Ω metal film resistor and a precision voltmeter in parallel at the sensor feedback pins of the 15-pin output connector of the LDT-5910C (pins 7 and 8) or the 25-pin output connector of the LDT-5940C (pins 14 and 15).

3. Enter the sensor calibration mode by pushing the parameter RECALL and mode SELECT buttons at the same time.
4. Press and hold in the parameter SET button and turn the ADJUST knob until the display indicates the same voltage as shown on the precision voltmeter.
5. Release the SET button and wait for the 7-segment display to exit the calibration mode and reflect the entered sensor resistance setpoint. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

RTD Sensor Calibration

The following procedure calibrates the 1 mA and 2.5 mA RTD temperature sensors so that the resistance measurements will be accurate. This procedure does not calculate R_0 , A, B and C. For information on calibrating the RTD sensor itself, see Application Note #4 Thermistor Calibration and the Steinhart-Hart Equation.

1. Under PARAM, set the SENSOR to 1 mA or 2.5 mA RTD.
2. Measure and record the exact resistance of a 1.2 k Ω (for the 1 mA) or 200 Ω (for the 2.5 mA) metal film resistors. A 4-point probe resistance measurement is recommended.
3. Connect the 1.2 k Ω or 200 Ω metal film resistor to the sensor feedback pins of the 15-pin output connector of the LDT-5910C (pins 7 and 8) or the 25-pin output connector of the LDT-5940C (pins 14 and 15).
4. Enter the sensor calibration mode by pushing the parameter RECALL and display SELECT buttons at the same time.
5. Press and hold in the SET button and turn the ADJUST knob until the display indicates the same resistance you recorded for the 1.2 k Ω or 200 Ω metal film resistor.
6. Release the SET button and wait for the 7-segment display to exit the calibration mode and reflect the entered sensor resistance setpoint. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

ITE Current Calibration

The following procedure calibrates the ITE constant current source for both polarities of current. During this procedure the ITE current is driven to two pre-determined values. When each of these values is reached and is stable, the user enters the actual value of the current, as measured by an external DMM. The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers then automatically calibrates the TEC current source and limits.

1. Connect a 1 Ω , 25 W resistor across the TEC output terminals of the LDT-5910C (pins 1 and 3) of the 15-pin connector or the LDT-5940C (pins {9, 10, 21, 22} and {12, 13, 24, 25}) of the 25-pin connector.
2. Enter the ITE calibration mode by pushing the parameter RECALL and display LEFT buttons simultaneously. Wait three seconds for the output to settle at 3 A. Calculate the actual current output by using Ohm's Law:

$$I = V / R$$

Where V is the accurately measured voltage across the resistor and R is the accurately measured load resistance. A 4-point probe resistance measurement is recommended.

3. Press and hold in the parameter SET button and turn the ADJUST knob until the display shows the absolute value of the ITE measurement as calculated from step 2.
4. Release the SET button. Wait three seconds to allow the ITE current to settle at -3 Amps.
5. Repeat step 3 for the new setpoint.
6. Wait for the 7-segment display to exit the calibration mode. Once the self-calibration is completed, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

TEC Voltage Measurement Calibration

The following procedure calibrates the TEC voltage measurement.

1. Calibrate the ITE current as described in the section above.
2. Measure the exact resistance of a 5 Ω , 25 W resistor
3. With the output off, connect the resistor across the TEC output terminals of the LDT-5910C (pins 1 and 3) of the 15-pin connector or the LDT-5940C (pins {9, 10, 21, 22} and {12, 13, 24, 25}) of the 25-pin connector.
4. Connect a calibrated DMM across the load resistor. Enter the calibration mode by pushing the RECALL and display RIGHT button simultaneously.
5. Using the measured resistance value, calculate the current needed to achieve 6 Volts for the LDT-5910C) across the 5 Ω resistor or 10 Volts for the LDT-5940C.
6. Adjust Iset to the calculated current by holding down the parameter SET button and turning the ADJUST knob.
7. Release the set button and allow at least three seconds for the instrument to settle at the current setpoint.
8. Measure the voltage using the DMM. Adjust V+ to the measured voltage by holding down the parameter SET button and turning the ADJUST knob.
9. Release the SET button and allow at least three second for the instrument to drive to negative Iset.
10. Measure the voltage using the DMM. Adjust V- to the measured voltage by holding down the parameter SET button and turning the ADJUST knob.
11. Release the set button. Once the self-calibration is completed and calibration mode is exited, the calibration constants will be stored to the non-volatile memory and the display will return to its previous state.

Appendix A:

AD590 and LM335 Sensor Calibration

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers use two constants (slope and offset) for calibrating linear IC thermal sensing devices, such as the AD590, and the LM335. Offset is used as the linear or zero offset value, and the slope is used as the slope or gain adjustment. Therefore, when accuracy is not critical, offset should be set to a nominal value of 0, and slope should be set to a nominal value of 1 when the selected sensor is an IC-I or set to a nominal value of 10 when the selected sensor is an IC-V.

In order to calibrate an IC sensor device, the sensor must be operated at an accurately known, stable temperature. For example, the sensor may be calibrated at 0 °C if the sensor is placed in ice water until its temperature is stable. A highly accurate temperature probe, thermometer, environmental chamber, etc., may also be used to determine the known temperature for calibration. This appendix contains one and two point calibration methods for IC sensor devices. These methods will work for either type of device.

AD590 Sensor

The AD590 is a linear IC thermal sensor which acts as a constant current regulator. It produces a current, I , which is directly proportional to absolute temperature, over its useful range (-50 °C to +150 °C). This nominal value can be expressed as:

$$I = 1 \mu\text{A} / \text{K}$$

Where I is the nominal current produced by the AD590, and K is the temperature in Kelvin.

The LDT-5910C and LDT-5940C Temperature Controllers use i to determine the nominal temperature, T_n , by the formula:

$$T_n = (I / (1 \mu\text{A} / \text{K})) - 273.15$$

Where T_n is in °C.

The temperature, T_d , which is displayed by the LDT-5910C and LDT-5940C, is first calibrated as follows:

$$T_d = C1 + (C2 * T_n)$$

Where offset and slope are the constants stored by the user in the LDT-5910C and LDT-5940C for the AD590.

The AD590 measurement is calibrated, at the factory, with $C2 = 1$ and $C1 = 0$ (nominal values). The AD590 grades of tolerance vary, but typically this means that without adjusting $C1$ or $C2$, the temperature accuracy is ± 1 °C over its rated operating range. If $C1$ and $C2$ are also calibrated, the temperature accuracy is ± 0.2 °C over its rated operating range. However, the AD590 is not perfectly linear, and even with $C1$ accurately known there is a non-linear absolute

temperature error associated with the device. This non-linearity is shown in Figure A.1, reprinted from Analog Devices specifications, where the error associated with C1 is assumed to be zero.

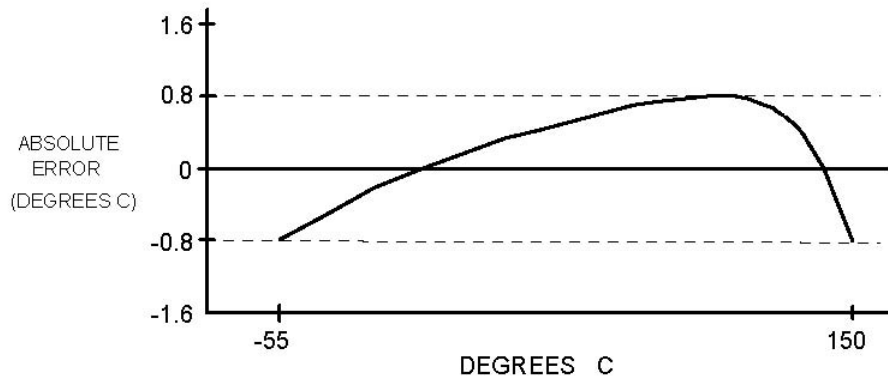


Figure A.1

If a maximum absolute error of 0.8 °C is tolerable (over the entire temperature range), the one point calibration of C1 should be used. If C1 is calibrated at 25 °C, and the intended operating range is 0 to 50 °C, a maximum error of about ±0.2°C may be expected over that operating range. If a greater accuracy is desired, the two point method of determining C1 and C2 should be used. Note however, the absolute error curve is non-linear; therefore, the constant C2 will vary over different temperature ranges.

LM335 Sensor

The LM335 is a linear thermal sensor which acts as a constant voltage regulator. It produces a voltage, V, which is directly proportional to absolute temperature, over its useful range (-40 °C to +100 °C). This nominal value can be expressed as:

$$V = 10 \text{ mV} / \text{K}$$

Where V is the nominal voltage produced by the LM335 and K is the temperature in Kelvin.

The LDT-5910C and LDT-5940C use V to determine the nominal temperature, T_n , by the formula:

$$T_n = (V / (10\text{mV} / \text{K})) - 273.15$$

Where T_n is measured in °C.

The temperature, T_d , which is displayed by the LDT-5910C and LDT-5940C, is first calibrated as follows:

$$T_d = C1 + (C2 / 10.0 * T_n)$$

Where C1 and C2 are the constants stored by the user in the LDT-5910C and LDT-5940C for the LM335.

When the LDT-5910C and LDT-5940C is shipped from the factory, the LM335 measurement system is calibrated, but the sensor (C1 and C2) is not. Nominally, C1 = 0, and C2 = 10. In that

case, the temperature accuracy is typically ± 1 °C over the rated operating range. With C1 and C2 calibrated also, the temperature accuracy is typically ± 0.3 °C over the rated operating range. The temperature accuracy may be improved over a narrow temperature range by a two-point calibration of C1 and C2. However, the LM335 is not perfectly linear, and even with C1 accurately known (and C2 uncalibrated) there is a non-linear absolute temperature error associated with the device. This non-linearity caused error is typically ± 0.3 °C, with the error associated with C1 assumed to be zero.

If a maximum absolute error of ± 1 °C is tolerable, no calibration of C1 or C2 is required, just set C1 = 0, C2 = 1. If a maximum absolute error of ± 0.5 °C is tolerable, the one point calibration of C1 may be used (see page C-5). If a greater accuracy is desired, the two point method of determining C1 and C2 should be used (see page C-6). Note however, the absolute error associated with the constant C2 may vary over different temperature ranges.

One Point Calibration Method

This procedure will work for any linear IC temperature sensor. The accuracy of this procedure depends on the accuracy of the known temperature, externally measured. It is used to determine the zero offset of the device, and it assumes that the gain offset (slope) is known and is correct.

1. Allow the LDT-5910C and LDT-5940C to warm-up for at least one hour. Set the sensor to the desired sensor type, and RECALL the constants for the particular device to be calibrated.
2. Select the C1 parameter. Read and record the value of C1.
3. Place the sensor at an accurately known and stable temperature, T_a . Connect the sensor to pins 7 and 8 of the LDT-5910C 15-pin connector or to pins 14 and 15 of the LDT-5940C 25-pin connector. Set the LDT-5910C and LDT-5940C for normal constant temperature (T mode) operation. Allow the LDT-5910C or LDT-5940C Temperature Controller to stabilize at the known temperature, T_a and read the displayed temperature, T_d .
4. Determine the new value of C1, C1n, from the formula:

$$C1n = C1 + T_a - T_d$$

and replace C1 with C1n by selecting the C1 parameter and entering the new C1n value.

Two Point Calibration Method

This procedure will work for any linear IC temperature sensor. The accuracy of this procedure depends on the accuracy of the known temperatures, externally measured. It is used to determine the zero offset of the device and the gain offset (slope).

1. Allow the LDT-5910C or LDT-5940C to warm-up for at least one hour. Set the sensor to the desired sensor type, and RECALL the constants for the particular device to be calibrated.
2. Select the C1 parameter. Read and record the value of C1. Select the C2 parameter. Read and record the value of C2.

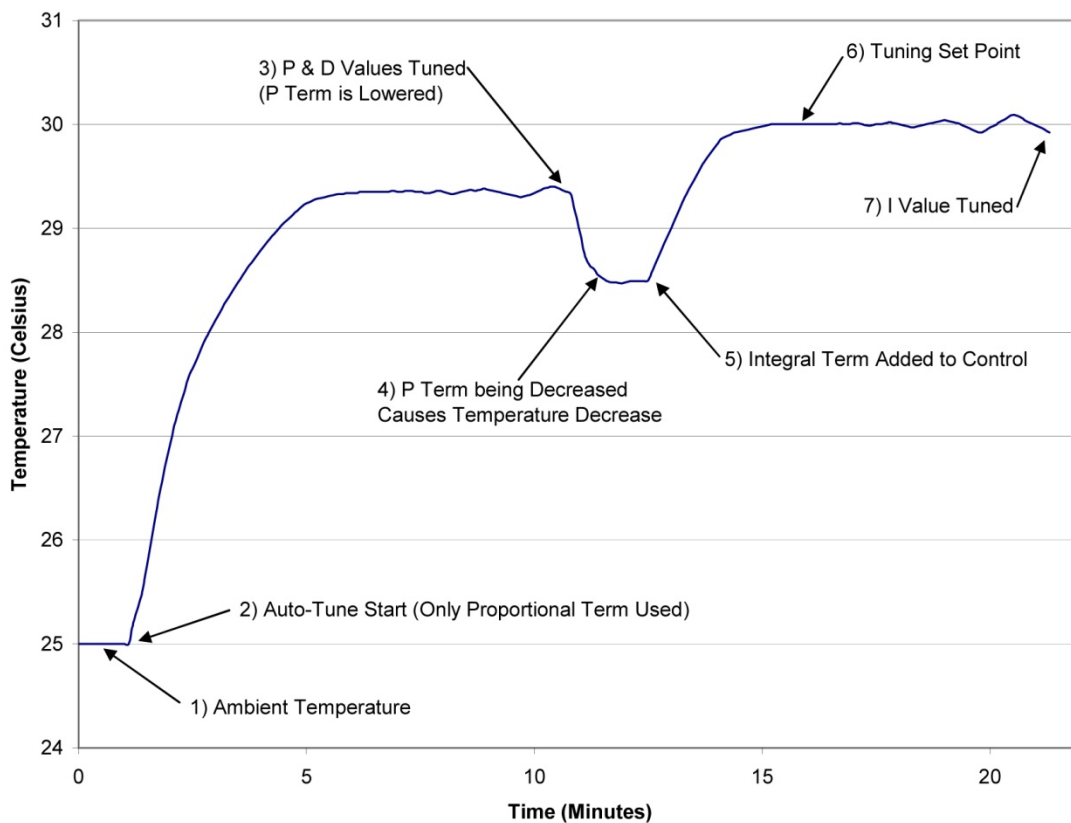
3. Place the sensor at an accurately known and stable temperature, T_{a1} . Connect the sensor to pins 7 and 8 of the LDT-5910C 15-pin connector or to pins 14 and 15 of the LDT-5940C 25-pin connector. Set the LDT-5910C or LDT-5940C for normal constant temperature (T mode) operation. Allow the LDT-5910C or LDT-5940C to stabilize at the known temperature, T_{a1} and read the displayed temperature, T_{d1} . Record these values.
4. Repeat Step 3 for another known temperature, T_{a2} , and the corresponding displayed temperature, T_{d2} . The two known temperatures should at the bounds of the intended operating range. The smaller of the two is intended operating range, the better the calibration over that same range.
5. Determine the new value of C1 ($C1_n$) and C2 ($C2_n$) from the following calculations. $\square \square$
 First determine the intermediate values U and V, where $V = (T_{a1} - T_{a2}) / (T_{d1} - T_{d2})$, and $U = T_{a1} - (T_{d1} * V)$ $\square \square$ Then $C1_n$ and $C2_n$ can be determined by the following: $\square \square$

$$C1_n = U + (V * C1) \text{ and } C2_n = V * C2$$
6. Replace C1 with $C1_n$ by selecting the C1 parameter and entering the new $C1_n$ value. Replace C2 with $C2_n$ by selecting the C2 parameter and entering the new $C2_n$ value.

Appendix B:

Auto-Tune Method

The LDT-5910C and LDT-5940C Thermoelectric Temperature Controllers currently use a single auto-tune method. The auto-tune algorithm will calculate a thermal system's appropriate PID coefficients through an iterative PID temperature control process. The figure below describes the tuning process pictorially.



The auto-tune algorithm starts controlling temperature (Point 2 on graph) with an arbitrary coefficient for the loop gain (P term), and slowly increases it until the temperature begins to oscillate. Once the temperature begins to oscillate, the P term is reduced by 40% and the D term is calculated (Point 3). The derivative term (D term) is calculated from the period of the oscillations that occurred during the tuning of the P term. The control loop is allowed to settle after the P and D terms are calculated and set. If the defined tuning setpoint is above the ambient temperature, the decrease in the P term will cause a decrease in the control temperature (Point 4).

After the temperature has stabilized, the integral term (I term) is then added to the control loop (Point 5 on graph). The I term is then increased until it causes the temperature to oscillate

around the user defined tuning setpoint (Point 7 on Graph). The final I term coefficient is set to 33% of the I term value that is found to start oscillations in the temperature control loop.

This tuning method calculates PID coefficients that result in fast settling times and good setpoint stability. The auto-tune algorithm slowly moves towards the oscillation points of the thermal system to consistently find suitable PID coefficients on a wide range of thermal systems, and to ensure that the thermal system will not be damaged. The calculated PID coefficients are dependent upon the user defined current limit and setpoint temperature. If a new setpoint temperature is desired that would require the controller to cool (vs. heat), the Auto-Tune feature can be used to calculate optimal PIDs for the new temperature setpoint. The tuning times of the auto-tune process will range from 2 to 10 minutes, depending on the thermal system being tuned. Typical tuning times are around 5 minutes. Thermal systems with higher P, I and D coefficients will take more time to tune than those with lower P, I and D coefficients.